No. 1 ESS Call Processing

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A telephone call goes through six basic stages: (1) detection of a service request, (2) interpretation of the digits dialed, (3) alerting the called customer, (4) establishing a talking connection, (5) call disconnect, and (6) charging. The way in which programs, assisted by circuits and temporary memory, advance a call from one stage to another in No. 1 ESS is described in this article.

I. INTRODUCTION

As mentioned in the description of systems objectives[1] for the No. 1 electronic switching system (ESS), the problem posed to the designer of a switching system intended for the widest possible Bell System use becomes: to provide economical means for switching a wide range of traffic, composed of many types of calls, each differing in some degree from the next.

Previous solutions to this problem resulted in systems composed of a multiplicity of switches and relay circuits, each performing a certain set of functions. A call was processed by the proper set of circuits at the proper time. In the more modern systems, common control circuitry takes over the most complicated parts of the decision-making process. For example, the No. 5 crossbar system, as presently developed, is so versatile that it is able to offer a wide range of services.

In the No. 1 ESS the principle of the common control has been carried even further by the use of a stored program electronic data processor, which consists of a central control and associated electronic memories. Relay circuits, such as trunk and service circuits, are kept as simple as possible.[2] Many of the functions performed by the circuits in previous systems are performed by the central control under the direction of the stored program.

The logical organization of the central control was designed to take advantage of the speed inherent in electronics for processing large num-

bers of calls. The variety of services is provided by the use of the stored program. A wide range of new services can be offered in the future with a fairly modest development of new circuitry. To provide existing offices with these new features will require few wiring changes, but will require a change of program.

The No. 1 ESS programs, like all large programs, are divided into functional blocks of instructions. Some of these blocks of instructions can be called on by other blocks to perform some specific function, such as looking up translation data in memory. Some blocks are basically concerned with an efficient input-output procedure. Others constitute the "mainline" programs, which advance the progress of the call. In all cases, similar programming actions are grouped together as much as possible so that a single program will suffice for many variations.

Each block of program requires the use of a "notebook" in temporary memory (call store) in which to leave data in the course of processing the call. In many cases, these areas of memory must be assigned at the start of a call and be kept intact over a period which usually lasts as long as a particular phase of the call. By analogy to relay registers which perform the memory function in relay systems, these areas of the call store are referred to as "registers." In dividing the total program into blocks, it is necessary to associate specific areas of the call store with only a few programs so that the formats of these areas need only be known to a limited number of programs. The need to engineer or assign areas of call store for most of the memory functions puts certain restrictions on the way the program is divided.

Although the basic job of the central control is call processing, certain administrative tasks are a necessary concomitant, such as taking traffic measurements and accepting data from the teletypewriter printer concerning changes made in the class of service and directory numbers assigned to lines. The stringent requirements for reliability which have come to be expected of telephone service have resulted in extensive maintenance programs designed to detect and diagnose equipment failures. In order to process a high volume of telephone traffic, the call-processing programs are largely separated from the maintenance and administrative programs. At specific points in normal call processing, checks are made to determine whether the system has behaved as expected; if not, maintenance programs are called in to determine the reason. Routine maintenance and administration functions are fitted in at times which will not hamper the system's basic tasks of call processing.

In the following sections of this paper the manner in which the system

supervises calls, receives and transmits signals, and connects calls in the switching network is described so that the program implementation can be more easily understood. The basic divisions of the call processing program are then outlined, and the corresponding organization of call store memory is described. Finally, a simple line-to-line call is traced to illustrate how the hardware, programs, and temporary memory are brought into play to process a typical call.

II. SUPERVISION AND SIGNALING

Each line has an appearance on a line link network.[3] Associated with each appearance is a line ferrod sensor,[4] which is used to detect the flow of line current when a telephone customer lifts his receiver to request service. Cutoff contacts of a ferreed switch remove the bridged windings of the ferrod sensor during signaling and conversation so that they will not impair transmission or limit signaling range. The line ferrod is the initial supervisory point for all line service requests, as shown in Fig. 1.

After a service request is detected, the line is connected to a digit receiver: a customer dial pulse receiver if the customer has a rotary dial on his telephone, a customer TOUCH-TONE receiver if the customer subscribes to TOUCH-TONE service. Either digit receiver provides dial tone to indicate that the system is ready to serve the request. In addition, the receiver is provided with facilities to test for crosses to foreign potentials which would simulate a service request, and to make a tip party test on two-party lines. The customer dial pulse receiver is capable of following subscriber dial pulses. The customer TOUCH-TONE receiver will both follow dial pulses and detect the presence of TOUCH-TONE signals. The digit receivers have appearances on trunk link networks. At the time a line is connected to a digit receiver, the

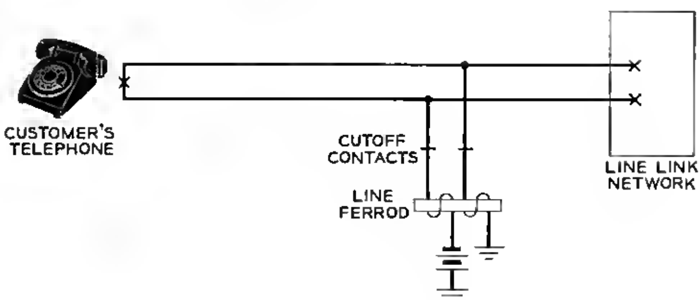

Fig. 1 — An idle customer line supervised at its line ferrod.

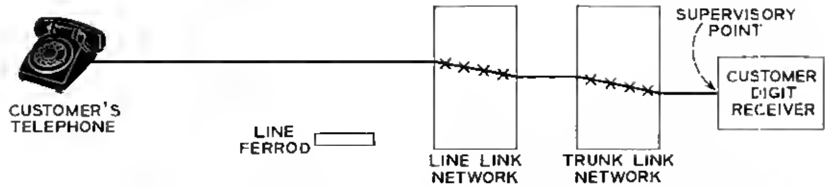

Fig. 2 — A line supervised at customer digit receiver during dialing.

cutoff contacts of the line ferrod are opened and supervision is transferred to the digit receiver, as shown in Fig. 2.

A line is supervised at a digit receiver until the completion of dialing, at which time the call will take one of many possible courses. If the requested number is in the same office, a ringing circuit will be utilized. If the requested number is busy, a connection to a busy tone circuit will be established. If the requested number is in another central office, an outgoing trunk and a digit transmitter will be brought into play. In the latter case, the supervision of the calling line normally remains at the digit receiver until the completion of outpulsing.

On an intraoffice call, audible ringing is supplied to the calling line by a tone circuit. The tone circuit provides audible tone and supervision of the calling line in order that a call abandonment during ringing may be detected.

Twenty-cycle ringing voltage is supplied through a small number of ringing circuits rather than through relays in the incoming or intraoffice trunk circuits, as in previous systems. Each ringing circuit has a trunk link network appearance and is connected to a called line only until the call is answered or is abandoned. Various line tests are made by the circuit. Power cross detection guards the ferreed crosspoints of the switching network and other circuits. A pretrip test guards against the possibility of falsely charging a calling customer, and a check is made that ringing current is flowing out toward the called phone. Three groups of ringing circuits are provided, one for each ringing phase, as shown in Fig. 3. The same is done for the audible tone circuits. When ringing is to be established, a connection to a ringing circuit in the active phase is made, providing virtually immediate ringing.

The ringing circuit is provided with a ring trip relay which stops the flow of ringing current as soon as the called customer answers. A scanner ferrod sensor provides the means by which a program detects the answer. Similarly, scanner ferrods are the means by which the results of the tests mentioned earlier are determined. The network connections and the points at which the calling and called lines are super-

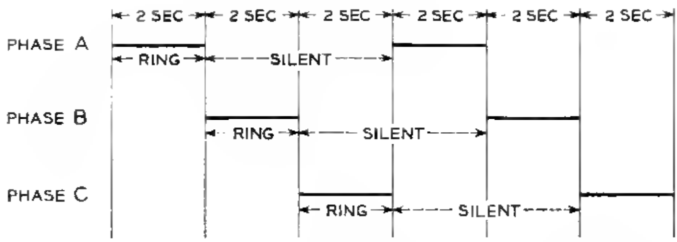

Fig. 3 — Three phases of ringing voltage provided for immediate ringing.

vised at this stage of an intraoffice call are shown in Fig. 4. At the time the ringing connection is established, the called customer's line ferrod is removed by opening its cutoff contacts.

On intraoffice calls, when customers are connected for talking, junctor circuits provide supervision and talking battery. Associated with each circuit are two scanner ferrod sensors, one to supervise each of the customers, as in Fig. 5. Bridged supervision is utilized and dc isolation is provided by the capacitor coupling used for speech transmission.

To summarize: the supervision of a calling line, during an intraoffice call, originates at its line ferrod, is transferred first to a digit receiver, then to an audible ringing tone circuit, and finally to one side of a junctor circuit. Abandonment of the call at any stage can be detected at one of these circuits. Similarly, the called line's supervision is removed from its line ferrod when a ringing connection is established and is transferred to the ringing circuit to detect answer. It is then transferred to the other side of the junctor circuit to detect its disconnect. Fig. 6 shows how supervision is passed from one circuit to another.

If the call destination is a customer in another central office, an outgoing trunk circuit to that office is selected and a digit transmitter is connected to the trunk circuit to transmit the called number. No. 1

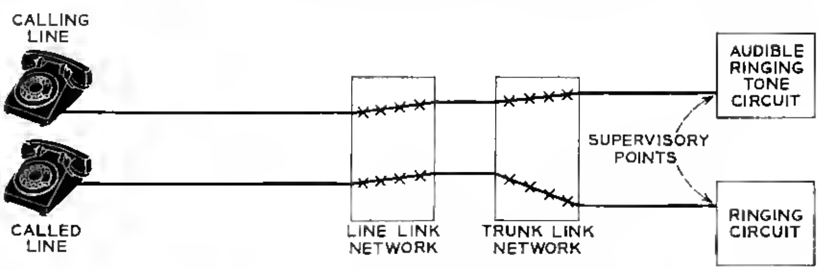

Fig. 4 — Supervision of calling and called lines during ringing.

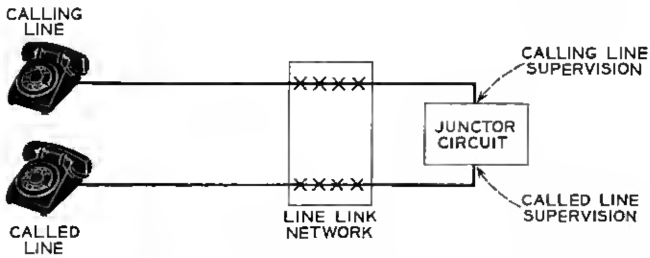

Fig 5.—Calling and called lines supervised at junctor circuit during talking.

ESS outgoing trunks are designed to provide: (1) supervision toward the calling line, (2) supervision toward the distant office, (3) speech transmission, (4) bypassing of all supervisory elements so that trunk tests can be made and pulsing can be performed by the transmitter, (5) compensation for different subscriber loop lengths, and (6) lightning surge protection.

Different types of digit transmitters are provided, to meet the needs of the offices which may be connected with No. 1 ESS. Dial pulse, multifrequency, revertive, and panel call indicator pulsing are available. Each transmitter, with an associated program, can test for the continuity and proper polarity of the trunks to which it connects, can detect start pulsing signals from a distant office, and can generate signals of the proper type.

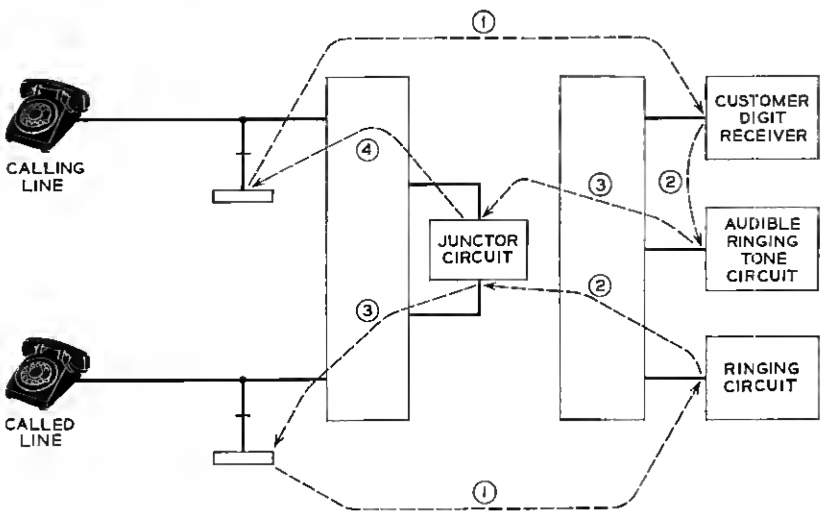

Fig. 6 — Transfer of supervisory points during an intraoffice call.

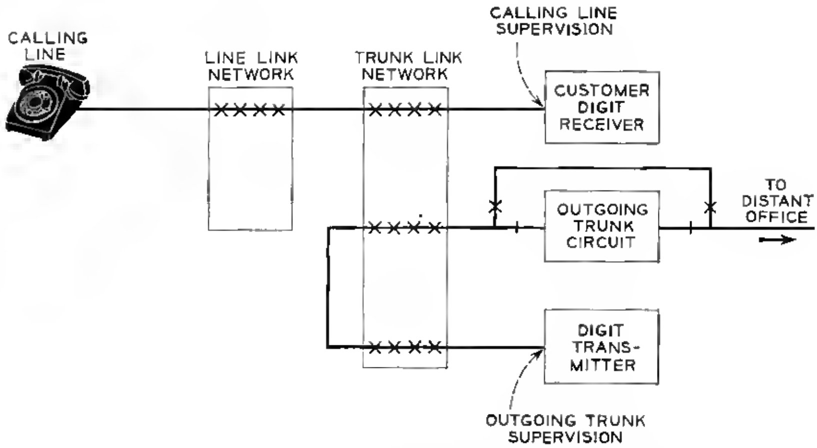

Fig. 7 — Supervision of an outgoing call during outpulsing.

Since a digit transmitter is connected to the selected outgoing trunk during the outpulsing stage of an outgoing call, the supervision of the calling line normally remains at the customer digit receiver until outpulsing is completed. Similarly, the outgoing trunk is supervised at the digit transmitter rather than in the trunk circuit. The network connections and supervisory points during outpulsing are shown in Fig. 7. After outpulsing, while ringing is being applied in the distant office, and during talking, the supervision of both the calling line and the trunk are at the trunk circuit, as shown in Fig. 8.

III. PROGRAMS INVOLVED IN CALL PROCESSING

In a program-controlled system such as No. 1 ESS, the circuits involved in advancing a call from one stage to another do not perform these actions by themselves. Control signals generated by programs

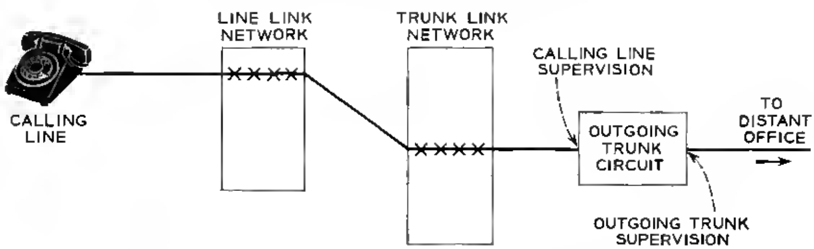

Fig. 8 — Supervision of an outgoing call during talking.

cause the circuits to change from one state to another. Similarly, control signals from the outside environment or changes in circuit states do not by themselves cause any system actions to take place. They activate scan points which are read and interpreted by programs. The programs determine the meanings of the scanner readings and perform the logic to decide what action should be taken.

The programs associated with call processing may be generally classified in three categories: (1) those which detect changes in the outside environment and constitute inputs to the ESS and those which produce changes in the outside world and constitute system outputs (these programs are referred to as input-output programs); (2) call control programs, which have only call-related purposes and whose function is to advance a call to completion; (3) programs of such a generally useful nature, which perform such a frequently used function, and which are sufficiently well defined that they may be considered to be service routines, used at will by call processing programs and others.

3.1 *Input-Output Programs*

3.1.1 *Input Programs*

The programs which detect system inputs are designed to be relatively simple, highly efficient programs which report changes or events to call control programs which analyze the report and perform any required actions. This is done because there is a very large number of inputs (scan points) to be interrogated regularly. The number of changes detected at any one time is expected to be quite small.

The program which detects line service requests interrogates all line ferrods in the office approximately ten times per second. The line scanners are arranged so that 16 line ferrod sensors are read simultaneously. The supervisory line scan program reports the origination to a call control program and continues its round of line scanner interrogation.

Another input program detects and counts dial pulses generated by customer dialing. It interrogates the scan points associated with the pulsing relays in customer dial pulse receivers 100 times per second. In addition to counting pulses, the program measures interdigital intervals and, when it determines that a string of dial pulses has ended, reports the count to a call control program which will determine whether any action should be taken. The program also performs two other auxiliary functions for which reports are made. One is to report when the first pulse of the first digit is detected, to tell the call control program that

it is time to remove dial tone. The second is to perform permanent signal and partial dial timing. If no pulses are received for an interval of 16 to 32 seconds, the program reports this to the call control program, which will handle the call from that point on.

A third input program scans the ferrods controlled by ring trip relays in ringing circuits. This program is activated ten times per second by an executive control program.[5] When the called customer answers, it reports to a call control program, which removes the ringing connection and establishes a talking connection.

The supervisory scanning program of junctor circuits looks only for changes from off-hook to on-hook. A change of state of a junctor ferrod from off-hook to on-hook may be a momentary hit on the line or an inadvertent switchhook jiggle. In addition, the customer may be flashing to initiate a special service request. Consequently, the supervisory junctor scan program reports the change to a hit-timing program which times the duration of the on-hook signal for an interval sufficiently long to discriminate among hits, flashes, and true disconnects. The result is reported to a call control program, which decides the appropriate action to be taken.

A trunk supervisory scan program detects a number of signals, because incoming trunks, outgoing trunks, and a variety of service circuits may be intermixed in a trunk scanner. The program can deduce some information from the changes which it is designed to detect. A change from off-hook to on-hook, for instance, indicates the start of a disconnect or a flash, and reports to the hit-timing program, which then performs the same timing functions as were described for the junctor supervisory program. A change from on-hook to off-hook on an incoming trunk constitutes a request for service, but on an outgoing trunk, it could indicate that the call was answered at a distant office.

The ability to discriminate between service requests on incoming trunks and answers on outgoing trunks is not built into the trunk supervisory program. It instead reports to a call control program that a change in the supervisory state of a trunk has occurred and goes on to see whether any more such changes have occurred on other trunk or service circuits. It is up to the call control program to sort out the requests from the answers.

3.1.2 *Output Programs*

When the No. 1 ESS data processor meets its external environment, it encounters an entirely different time scale. The program processes

parts of a call at a very high speed and on a time-shared basis. To operate relays in trunk circuits, activate network controllers, record call charge information on magnetic tape, or transmit a teletypewriter message takes a relatively long time. The processing of other call elements cannot be delayed to wait for these actions, so the program determines what action needs to be performed and buffers data for an output program which specializes in converting the buffered data to the desired action.

Outputs are distributed by the No. 1 ESS peripheral bus system to signal distributors, network controllers, teletypewriter control circuits, and others. The data, consisting of addresses and control information, are stored in temporary memory areas called peripheral order buffers (POB's). The program which controls the transmission of the data is called the peripheral order buffer execution program. It is responsible for seeing that the correct addresses and instructions are sent to the controllers, checking that the proper action was taken in response to the instructions, and reporting back to the call control program the success or failure of the requested action.

3.2 *Call Control Programs*

Each call control program performs a specific function, usually related to a stage in the progress of a call. This separation permits each program to be of a manageable size and to perform a reasonably well defined function. It also makes the addition of new features relatively easy, since the new feature will only affect a few programs.

On a normal intraoffice call, the call control programs which are brought into play and which are responsible for the handling of the call at various stages are: (1) the dialing connection program, used to set up a dialing connection; (2) the digit analysis program, used to record and analyze the digits dialed, and to determine the destination of the call; (3) the ringing and answer detection program, used to establish the ringing connection, detect the called customer's answer, and establish the talking connection; and (4) the disconnect program, used to control the disconnect of the call and restore the lines to the idle state.

3.2.1 *Dialing Connection Program*

A report from the supervisory line scan program that a line has requested service is the input to the dialing connection program. To serve the request, there are several things that this program must do. First, it must find a block of temporary memory in which to store data regarding

the calling line and the number that the customer will be dialing. Then it must acquire some information about the line. Does the customer have a rotary dial telephone or a TOUCH-TONE telephone? Is the line an individual, two-party, or four-party line? A PBX trunk? A coin line? Is it a disabled customer who is not able to dial? Has the line been denied service for some reason?

When the answers to the above questions have been obtained, the program knows what it must do. It must select an idle customer digit receiver of a type which is compatible with telephones on the calling line. It must cause a network connection to be made from the calling line to the selected digit receiver. After the connection has been established and the line cutoff contacts opened, it must cause the digit receiver to apply its power cross detection circuitry to the line and read a scan point to determine the results of the test. Next, it must cause the digit receiver to remove the power cross test circuit from the line and, for a two-party line, to apply a party test circuit and then read a scan point indicating the result of this test. After all the necessary tests have been performed and passed, the program causes a relay in the digit receiver to operate and connects a supervisory relay and dial tone to the line. The transfer of supervision from the line ferrod to the supervisory relay in the digit receiver is then checked by reading another scan point. After all the above have been successfully accomplished, the program activates the dial pulse scan program with respect to the chosen digit receiver. Fig. 9 represents the functions of the dialing connection program.

It should be noted that the dialing connection program *causes* the actions mentioned to be taken in the digit receiver, and it *causes* a network connection to be made. It does *not*, by itself, perform these actions in the order stated. Instead, it calls upon the services of the network control program to find an idle path from the line to the digit receiver and to load the network controller addresses and instructions in a peripheral order buffer (POB). The dialing connection program then calls on the circuit control program to load the desired relay and scan actions in the POB. After the buffer loading is complete, the POB execution program removes the instructions from the buffer one at a time until it is emptied. The POB execution program then reports back to the dialing connection program that the job was done successfully. If trouble developed along the way, such as a cross to a foreign potential or a failure to transfer supervision, the rest of the actions would have been skipped and a failure report would have been returned to the dialing connection program.

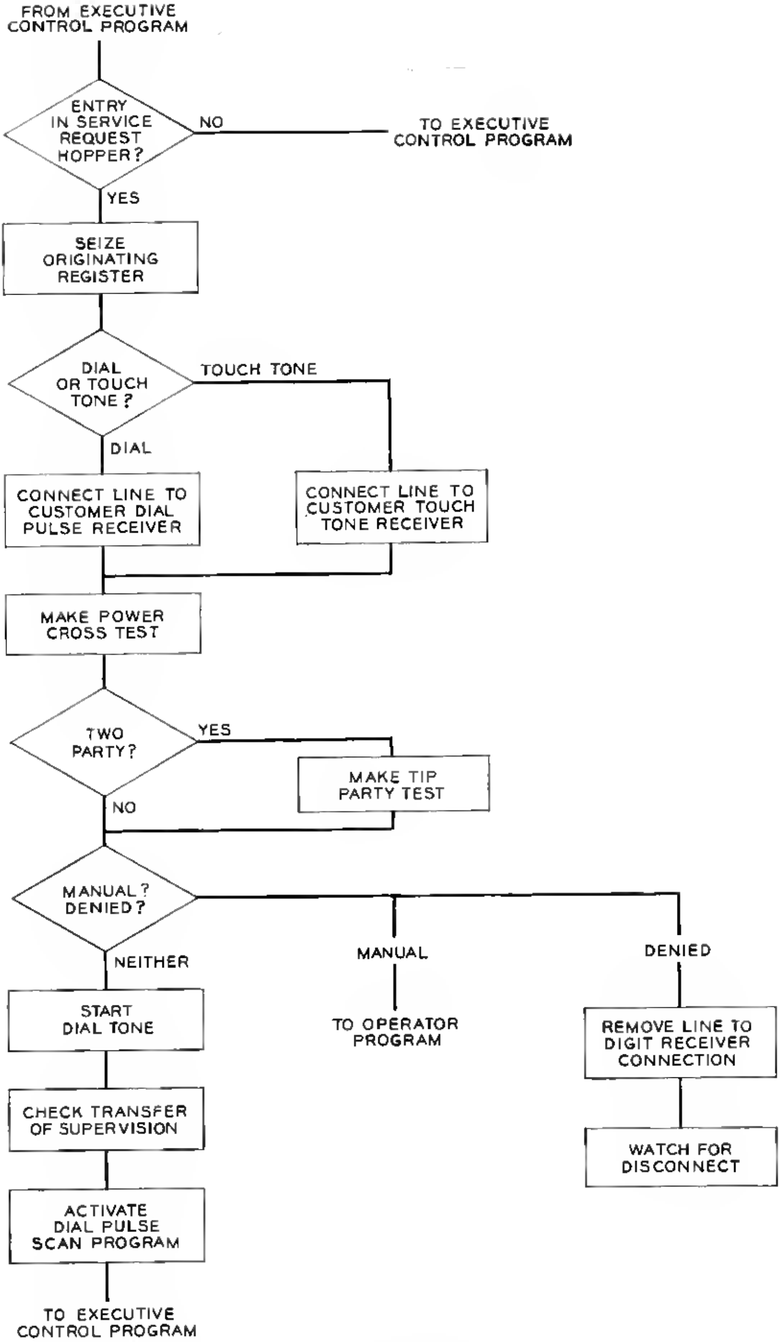

Fig. 9 — Functional flow chart of dialing connection program.

3.2.2 *Digit Analysis Program*

The responsibility of the dialing connection program ends with a successful report, and control of the call is passed to the digit analysis program. This program is responsible for recording, counting, and interpreting the customer's digits as they are dialed, determining the routing of the call if a valid number is dialed, determining whether a called number is busy or idle, and determining what the disposition of a call should be if it cannot be completed.

The dial pulse detection or the TOUCH-TONE digit detection input-output programs provide information to the digit analysis program by reporting to it when a digit is received, when an abandonment is detected, when the first dial pulse of the first digit is received, or when a permanent signal or partial dial time-out is detected. The program counts and stores the digits as they are reported to it in the temporary memory space (register) reserved by the dialing connection program. As the digits are received, some are merely counted and stored. For others, an analysis of the digits which have been received is made to determine what course to follow. For instance, when the first digit is dialed, the program determines whether the digit is zero (ten dial pulses). If so, dialing is finished and the call is directed to an operator. Control of the call then passes to a program which controls connections to switchboard operator's trunks. Any other digit (except the digit one, which is not a valid first digit of any area or office code) is stored, and a digit counter is incremented by one. Upon receipt of the third digit, an analysis of the first three digits is made. If the service code, 411, has been dialed, it is known that a connection to an information operator is desired. Dialing is finished, and control is passed to a program which will perform the desired action. Other three-digit codes are treated in a similar manner. If the first three digits are an office code in the same numbering-plan area, four more digits are expected. If the first three digits are those of a foreign area code, it is known that seven more digits must be received in order to be a valid number. The routing of the call can often be determined at this time. The office or area code determines whether it is an intraoffice call or an outgoing call. If the call is outgoing, it may be possible to determine the first-choice trunk group. However, some codes require six digits to be dialed before a route can be chosen.

Additional digits beyond the third are merely stored and counted until seven or ten have been received, depending upon whether a home numbering-plan office code or a foreign numbering-plan area code has been dialed. If the call is outgoing, the digit analysis program selects an

outgoing trunk to the distant office, selects a digit transmitter of the proper type, causes a connection to be established between them, and then passes control to an outpulsing program which will seize the trunk, make the necessary tests, and transmit the called number to the distant office.

On a call destination within the No. 1 ESS, the digit analysis program acquires some information regarding the class of the called line, finds out whether the line is busy or idle and, if idle, passes control to the ringing and answer detection program.

The digit analysis program also finds out whether a charge is to be made for the call. If so, it notifies a program which records the pertinent information.

If, during the dialing of the call, the customer hangs up and abandons the call, the digit analysis program causes the network connection to be removed, idles the digit receiver, and releases all temporary memory.

Permanent signal and partial dial reports are merely passed on to a program designed especially to take care of these conditions. Fig. 10 is a functional flow chart of the digit analysis program.

3.2.3 *Ringing and Answer Detection Program*

The ringing and answer detection program, as its name implies, controls all system actions on intraoffice or incoming calls from completion of dialing until answer. Its basic job is to connect ringing to the called line, connect audible ringing tone to the calling line or trunk, establish a talking connection if the call is answered, and remove all connections if the call is abandoned before answer.

The network locations of the lines and the type of ringing to be applied to the called line are needed to set up the ringing connection. The information regarding the calling and called lines (on an intraoffice call) is passed to the ringing and answer detection program by the digit analysis program. With this information, the ringing and answer detection program calls upon the services of the network control program, asking it to: (1) find idle circuits connected to the active phases of ringing and audible ringing (it was mentioned earlier that three groups of regular ringing trunks and audible ringing tone trunks are furnished, one for each phase of ringing to provide immediate ringing; the ringing and answer detection program keeps informed of which ringing phase is active); (2) find an idle path from the calling line to the selected audible ringing tone circuit; (3) find an idle path from the called line to the ringing circuit; (4) reserve a path from the calling line to the called line;

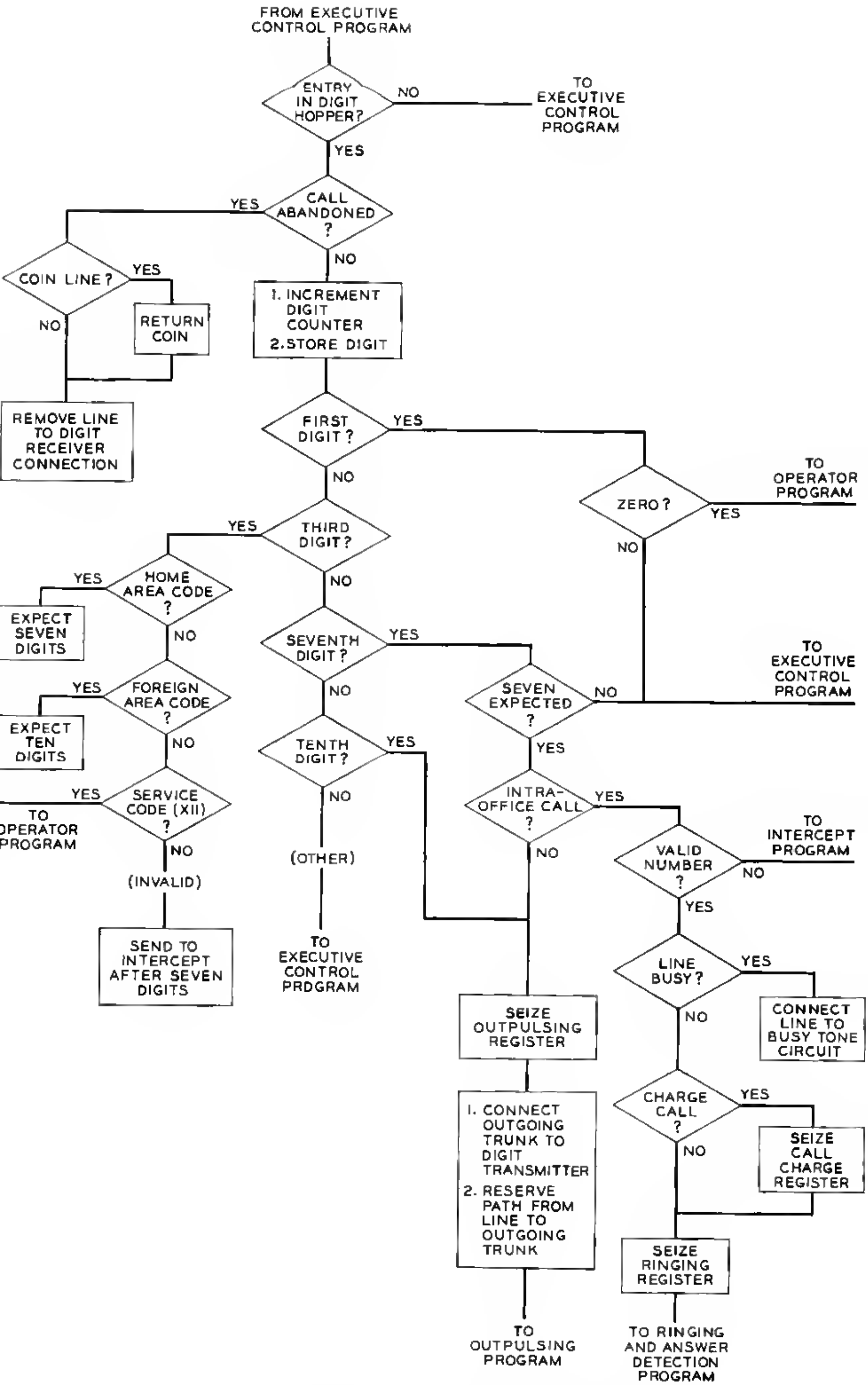

Fig. 10 — Flow chart of digit analysis program.

and (5) load the instructions for making the two connections into the peripheral order buffer.

The ringing and answer detection program next calls upon the services of the circuit control program to load further instructions in the POB which will cause the ringing circuit to perform a power cross test, a pretrip test, and a continuity test. The circuit control program also loads instructions to operate relays in the circuits which will apply twenty-cycle ringing voltage to the called line and audible ringing tone to the calling line in addition to checking that transfer of supervision has taken place at the audible tone circuit.

The job of the ringing portion of the program is almost complete at this time. All that remains is to activate the POB, wait until the POB execution program reports its success in completing the list of instructions, and activate the input-output programs which scan the ring trip ferrods and the audible ringing tone circuit supervisory ferrods.

An answer by the called party causes the ring trip relay to operate and saturate the ring trip ferrod. The answer is detected by the ring trip scan program and is reported to the ringing and answer detection program. Upon receipt of the report, the ringing and answer detection program again calls upon the services of the network control program and the circuit control program to release any operated relays in the ringing and audible circuits, to idle the two network paths, to set up a new path from each line to a junctor circuit, and to check that the supervision of each line is transferred to the junctor circuit.

If a charge is to be made on the call, the ringing and answer detection program reports the answer to the call charge program, which will record the time of answer.

After the ringing and answer detection program activates the input-output program which scans the junctor supervisory ferrods for disconnect, it finishes its responsibility for advancing the progress of the call. Fig. 11 is a flow chart of the functions performed by the ringing and answer detection program.

3.2.4 *Disconnect Program*

Unless a special service call or a coin call is in progress, no other call control program is called into play until one of the customers hangs up. At this time, on an intraoffice call, the junctor supervisory scan reports the event to the disconnect program. Hit timing will already have been performed by a program associated with the junctor supervisory scan program.

The functions of the disconnect program are: to detect flashing for

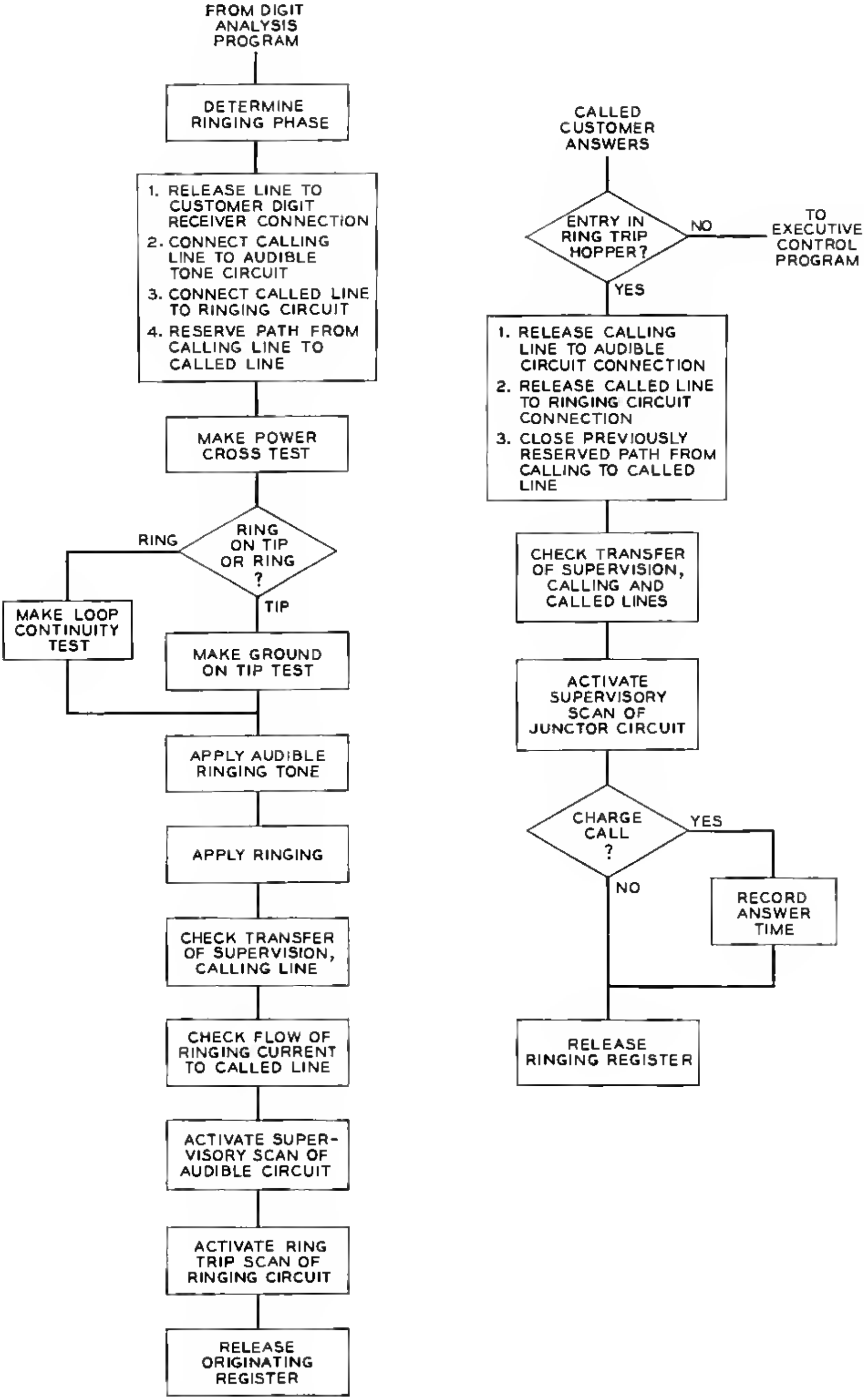

Fig. 11 — Ringing and answer detection program flow chart.

special services from those lines permitted to flash; to provide calling line control of the call (yet not permit it to keep a called line permanently tied up); to signal disconnect to a distant office over an incoming or outgoing trunk; to remove a talking connection at disconnect; to restore to idle any lines or trunks involved in the call; and to call in other programs to handle special conditions.

To determine the treatment for a disconnecting line, the program first finds out some information about the line. Is it the calling or called party? Is the line a coin line? Does it have any special services? Has the other end already disconnected? On an interoffice call, is it the line side or trunk side that is disconnecting? An incoming or an outgoing trunk? Is a charge record being made? Different actions are called for, depending on the answers to these questions.

On an intraoffice call, if the disconnect is from a *calling* line with no special services, the program knows that it does not have to perform flash timing. Because calling line control is provided, it is known that the call is over. The connection is not immediately removed, however, unless the *called* line has disconnected also. The program waits a reasonable length of time to permit the other party to hang up so that the line still off-hook does not appear to the system as a false request for service. When it detects the disconnect, it then calls upon the services of the network control and circuit control service programs to remove the network connection, to idle the junctor circuits, and to restore and check the line ferrods of the two lines.

The people involved in the conversation, however, may not perform the actions in the order given above. The called party may not hang up his phone within a reasonable time (10 to 12 seconds), or the calling customer may initiate another call very shortly after hanging up and before the called party replaces his receiver. In either of these cases, the network connection is removed and the lines are idled.

A called customer, upon disconnecting first, is permitted 10 to 12 seconds during which he may pick up his telephone and still find his original connection existing — if the calling customer has not hung up in the meantime.

The disconnect program calls in a coin control program when it knows that a coin line disconnects, in order that a coin-collect or coin-return action may be performed. A functional flow chart of the disconnect program is shown in Fig. 12.

3.2.5 *Other Call Processing Programs*

To handle call types other than the simple intraoffice call, other call control programs exist. Each is designed to take care of a particular

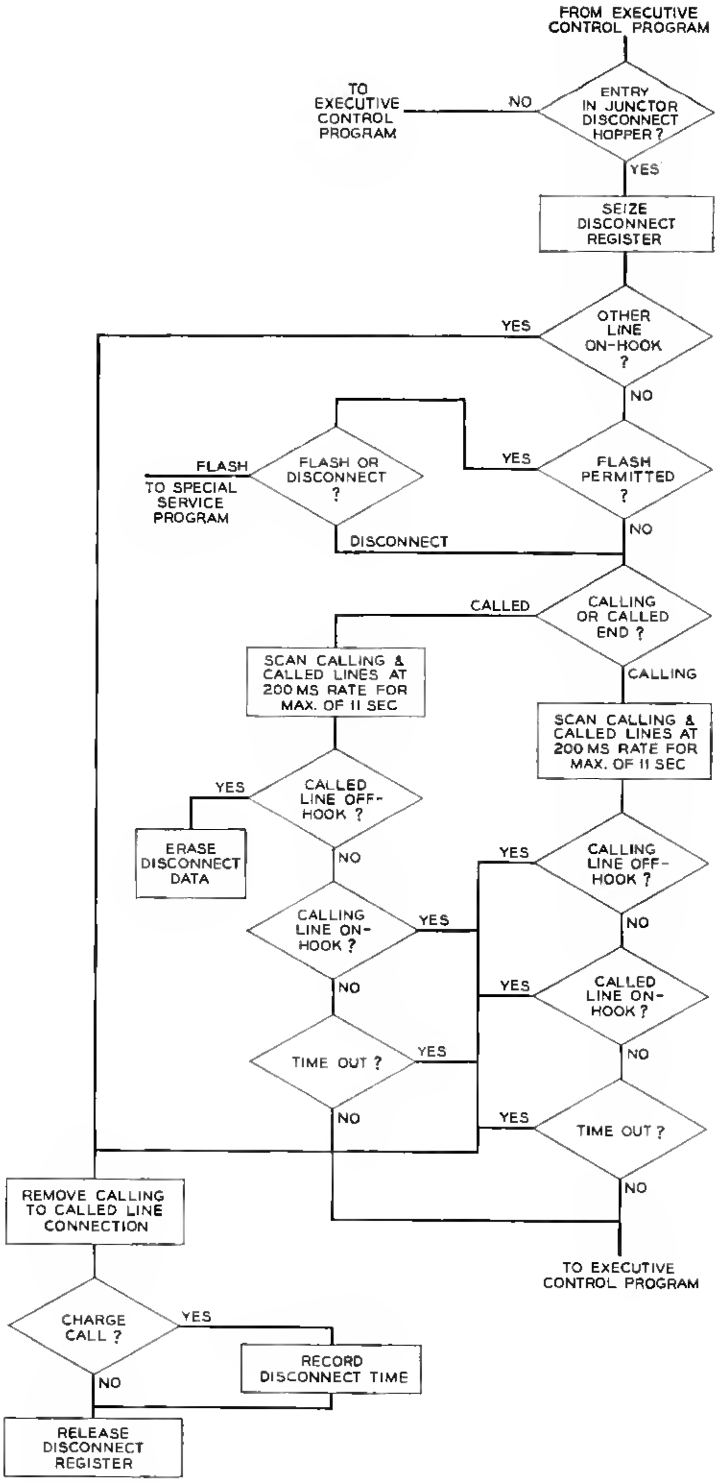

Fig. 12 — Program flow chart for disconnect of an intraoffice call.

stage of a call's progress or a particular type of call. A partial listing and a brief description of each follows:

3.2.5.1 *Outpulsing Program.* A call terminating in another central office requires that the called number be transmitted to that office in a form which it is prepared to accept. Several forms of signaling have developed over the years, and No. 1 ESS must be prepared to perform any of them. They are: dial pulsing, revertive pulsing, multifrequency pulsing, and panel call indicator pulsing. Since each is quite different from the others, a different program is designed for each.

To make an outpulsing program universally applicable to a number of call situations, the call procedure is designed so that a network connection between a digit transmitter and an outgoing trunk will already have been established. The outpulsing program then causes the outgoing trunk and the transmitter to be set in the proper states to test the continuity and polarity of the pair of leads to the distant office, to send a seizure signal, to detect a start pulsing signal, and then to cause the called number to be transmitted. It does this with the cooperation of input-output programs that are capable of generating dial pulses, multifrequency pulses, etc. The outpulsing program gives the dial pulse generating program (for instance) a digit. The dial pulse generating program forms the necessary number of dial pulses, measures an interdigital interval, and reports that a digit has been transmitted. The process is repeated until all required digits have been sent. Prefixing or deletion of digits is predetermined by the digit analysis program

3.2.5.2 *Operator Programs.* The actions required for calls to switchboard operators are different from those for other call types. As soon as a call is made to an operator, control is passed to the operator program. Calls to assistance and toll operators provide for joint holding, and these operators are permitted to ring back to a busy or an idle line. The operators also collect and return coins. In addition to the assistance and toll operators, there are information operators, business office operators, intercept operators, and repair service operators, all with their own functions and signaling arrangements.

3.2.5.3 *Permanent Signal and Partial Dial Program.* Those call attempts which become permanent signals or partial dials are handled by a program designed to switch the call first to an announcement requesting that the customer hang up and then to a distinctive receiver off-hook tone for a timed interval. If these actions do not succeed in removing the condition, the program connects the line to an operator to see whether she can provide assistance, and then to the master control center for a maintenance man to test the line conductors (he determines whether a trouble condition exists). The permanent signal and partial dial pro-

gram guides the call through the various steps, performing the timing functions and requesting the needed network connections and relay operations in the circuits which are involved.

3.2.5.4 *Traffic Measurement Programs.* To determine the traffic levels in a No. 1 ESS office, a number of traffic measurements are made. Traffic engineers make use of peg counts, overflow counts, and usage counts to tell whether the number of circuits of various types or the number of trunks in various routes should be increased or decreased to carry the offered traffic.

A separate program can continuously generate service requests to measure and count the number of attempts on which excessive dial tone delays are experienced. The results of the traffic measurements are printed by a teletypewriter printer on a regular schedule.

3.3 *Service Routines*

Most call control programs use a number of service routines while controlling the progress of a call. Examples of service routine usage are: to request a change in a network configuration, to request the operation or release of a relay in a trunk or service circuit, and to obtain translation information. These service routines are used not only by the call control programs but also by the maintenance and diagnostic programs.

Because the service routines serve many clients under varying conditions, rules are established which must be obeyed whenever the service routines are used. The presentation of certain data in a certain format will cause a particular action to be performed, or particular translation information to be obtained. In use, the client sets up the necessary data in a prescribed manner and then passes control to the service routine. When the service routine finishes its requested action, it returns control to the client with data useful to the client in a predetermined location.

3.3.1 *Network Control Program*

The primary functions of the network control program are to hunt for idle network paths, to administer the network map and path memory, and to load instructions in POB's, which will be used to close network paths.

In the process of performing these functions, the network control program is provided with the ability to find an idle trunk in a group, to make a second trial if all the paths to the first selected trunk are busy, and to consult the translation program to find an alternate route if all trunks are found busy in the first-choice route.

Since the record of the busy or idle condition of all links in the switching network is kept in temporary memory (called the network link map), the network control program can reserve a path from one terminal to another for expected use at a later stage of a call. Similarly, the information regarding a connection established in the network is kept in temporary memory associated with network terminals (called path memory). The network control program records pertinent information about a path at the time a connection is made or removed.

3.3.2 *Circuit Control Program*

When a call control program determines that a change of state in a trunk circuit or service circuit is required to make a test or cut through a talking pair, the call control program calls upon the services of the circuit control program. It need only inform the circuit control program of the type of circuit to be used and the function to be performed. The circuit control program will then load the POB with the signal distributor operations necessary to implement the change and any scanner actions needed to check that the operation was performed successfully.

3.3.3 *Translation Program*[6]

Translations from line equipment number to calling line class and directory number, from office code to routing information and charge class, and from directory number to line location and class, are needed in the No. 1 ESS just as they are in other common control systems. Instead of this information being obtained by wired cross-connection fields, it is contained in tables stored in memory. The translation program gains access to the translation tables.

3.3.4 *Coin Control Program*

The collection and return of coins in coin phones is performed by a small number of coin control circuits in No. 1 ESS. A program which specializes in performing the functions required for these actions may be called in by any other call control program. In order for another call control program to use the coin control program, it must first establish a connection from the coin line to the coin control circuit and inform the coin control program whether a collection or a return is to be made.

The principal programs used in processing calls in No. 1 ESS are shown in Fig. 13. The connecting lines indicate transfer of information or of control.

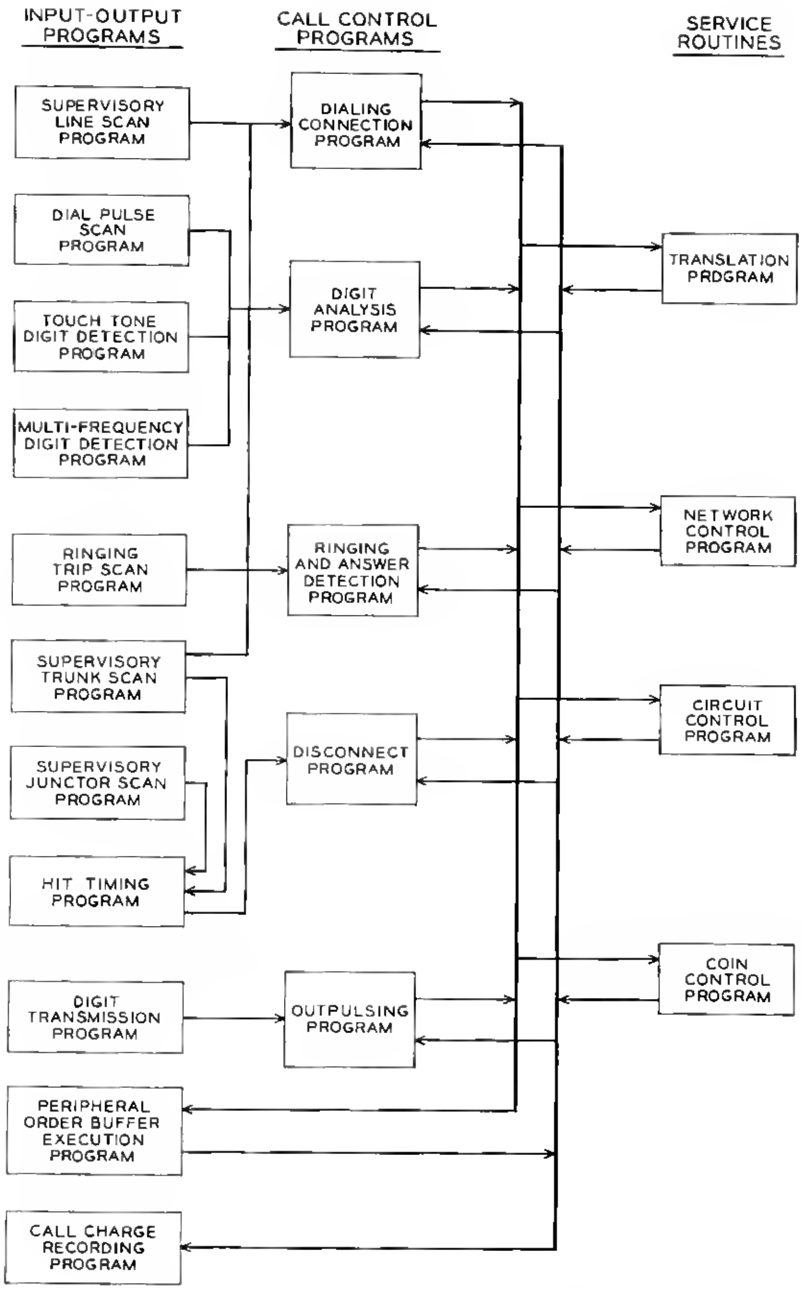

Fig. 13 — Programs used in processing calls.

IV. TEMPORARY MEMORY

Associated with the input-output programs, the call control programs, and the service routines, there are always data which change with the activity on a line or trunk, or with the progress of a call. These changeable data are kept in a temporary memory called the call store. Just as functional blocks of programs may be classified as being associated with system inputs and outputs, with call processing, or with service routines, so blocks of temporary memory may be associated with the same functions. The proper recording of information in temporary memory provides the means by which the various parts of a call are linked together and coutinuity of the call is maintained.

4.1 *Input-Output Oriented Memory*

Temporary memory is associated with each scan point of a line, junctor or trunk scanner in order to keep a record of the supervisory state of the facility connected to it. This memory is used primarily by the supervisory programs in detecting requests for service, disconnects, and answers. Since only service requests can be detected at a line ferrod (it is disconnected by cutoff contacts when a digit receiver is attached and not restored until disconnect), one line supervisory memory bit is associated with each line ferrod. The supervisory line scan program simultaneously reads the ferrod and the line supervisory memory, compares them and, if the line supervisory memory reads idle while the ferrod shows an off-hook condition, deduces that the customer has lifted his receiver. The scan program reports this to the dialing connection program. In the process, the line supervisory memory is marked to indicate that further readings of the bit should be ignored. In this sense, the line supervisory memory serves as a memory of the previous scanner reading and also as a busy or idle indicator for the line.

Each junctor circuit has two ferrods which supervise the two parties during talking. The customers can disconnect from the talking state only when connected to a junctor circuit; thus only one bit of temporary memory is needed for each junctor scan point. The junctor supervisory memory serves a purpose similar to the line supervisory memory in indicating the previous scanner reading.

Trunk supervisory points are multifunctional in that originations, answers, and disconnects are signaled to the system by them. Different trunk circuits and service circuits that have varying numbers of scan points appear on the same scanner in a pattern that changes from office to office. For these reasons, each scan point of a trunk scanner is assigned

two bits of temporary memory. These two bits are used to indicate: (1) that the facility is idle and may originate a request for service; (2) that the facility is in a talking state and should be monitored for disconnect; or (3) that the scan point may be changing for other reasons, such as signaling, and that the supervisory trunk scan should ignore any changes that it sees.

The digit receivers and digit transmitters each have associated temporary memory, which may be thought of as an extension of the circuits themselves. For instance, a relay in the dial pulse receiver is capable of following dial pulses. The relay activates the same scan point on each dial pulse. The dial pulse scan program, in conjunction with the temporary memory associated with the receiver, keeps a count of the pulses as they are received. Then, at the end of an interdigital time-out interval, the digit is reported to the digit analysis program, which counts and stores the digit in temporary memory. This is analogous in crossbar systems to a pulsing relay operating a set of counting relays and transfer of the pulse count at interdigital timeout to a set of register relays, steered by a digit counting circuit. Provisions for permanent signal and partial dial timing are also made, both in the No. 1 ESS and in crossbar systems.

A number of calls are being dialed into, or pulsed out of, the system at any one time. Therefore, there must be a way to keep a particular digit receiver and its temporary memory associated with a particular call. A call control register serves as the controlling register for the call. Its address is stored in the dialing register associated with the digit receiver serving the call. The dialing register is often referred to as a junior register.

Similar registers, differing slightly in use and format, are associated with TOUCH-TONE receivers, multifrequency transmitters and receivers, revertive pulse transmitters and receivers, and panel call indicator transmitters.

Another register closely associated with input programs is the hit timing register, which assists in timing disconnects to insure that hits do not cause false disconnects. This register also assists in performing the functions of timing for flashes and called party disconnects, as a service for the disconnect program.

4.2 *Hoppers*

Because the number of input-output actions is very large in wire centers served by No. 1 ESS, and because the system must meet very

tight timing requirements for certain of its input-output programs, it is necessary to limit the continuous length of processing time devoted to any given input. When a given input is detected that requires the attention of a call control program, the input program reports its finding in an area of call store called a hopper. Each input-output program is assigned one or more hoppers in which it stores information. A call control program, scheduled at a later time by the system's executive program, removes the information from the hopper and uses it to advance the call with which the information is associated. This permits the high-priority input-output program to concentrate on interrogating as many lines, trunks, digit receivers, or transmitters in as short a time as possible. The program has only to load some data in a hopper and continue, rather than interrupt its primary input-output function to perform more complex and less urgent tasks.

Since the data reported by the input-output programs are associated with a particular call, the identity of the call is stored in the hopper along with the data. The line supervisory scan program, for instance, reports to the dialing connection program through the service request hopper. The information stored in the hopper is the line equipment number, the only identification available at this stage of a call.

The dial pulse detection program, however, reports to the digit analysis program through three different hoppers, each reporting a different event: the dial pulse digit hopper reports digit counts and call abandonments; the remove dial tone hopper reports the receipt of the first digit; the permanent signal and partial dial hopper reports the named events. In each case, the identifying datum is the originating register address.

A partial list of hoppers, the names of which are self-explanatory, follows:

line service request hopper
dial pulse digit hopper
TOUCH-TONE digit hopper
multifrequency digit hopper
revertive pulse digit hopper
remove dial tone hopper
permanent signal, partial dial hopper
ringing trip hopper
junctor disconnect hopper
trunk disconnect hopper
peripheral order buffer execution result hopper
request outpulsing digit hopper
request teletypewriter character hopper.

4.3 *Output Buffers*

The peripheral order buffer execution program has been described as one of the principal means by which No. 1 ESS controls the switching network and various trunk, junctor, and service circuits. The peripheral order buffer is the temporary memory area used to list the network controller, signal distributor, central pulse distributor, and scanner actions necessary to accomplish a desired result. The number of these areas is variable and dependent upon the expected traffic load in the office.

In addition to the list of instructions to be carried out, the POB contains a cross reference to the call control register for which it is performing a service and to one or more program addresses to which it returns to report success or failure.

Similar in character and in operation to the POB are the buffers provided for transmitting teletypewriter messages and for recording call charge information on magnetic tape. The characters for a teletypewriter message are placed sequentially in a teletypewriter buffer and then are removed and converted to teletypewriter code, one character at a time, at a rate compatible with the transmitter. Call charge information is placed on magnetic tape in blocks of 500 characters. A buffer to accommodate this function is furnished. When a block of 500 characters is filled, an unloading program transfers the data to tape.

The output buffers for digits to be outpulsed to a distant office are those registers which are associated with digit transmitters and which are used by the input-output programs.

4.4 *Call Control Registers*

Call-processing registers are blocks of temporary memory used by call control programs to store data during a particular stage of the progress of a call. The information needed by different functions is not necessarily the same in content or amount; therefore, call control registers associated with different functions will differ in size.

All call control registers have a standard format. The first four words (a word consists of 23 bits) of any call control register are used for specific storage purposes. The first word of a call register contains the identity of the register and call state; this word is referred to as the state identifier. The second, or queue, word is used to insert the register on a waiting or a timing list. The third word is called the link word, used to hold another call control register's address if more than one register is associated with the call. The fourth, or scan, word contains the address of a scan register

if the call control program has requested scanning of some particular point or points. The next group of words in any call control register is set aside for network path memory. This storage area is referred to as the path memory annex and may differ in length from one type of call control register to another. The storage area following the path memory annex area is called the data area of the register, and its size is dependent on the data needed by the associated call control programs.

A brief description of the major call control registers used in the No. 1 ESS follows.

The originating register is used by the dialing connection and digit analysis programs. The path memory annex consists of two words and contains the path memory necessary for the connection from the originating line to the digit receiver. The data area of the register must hold the address and the class information of the originating line, the dialed directory number, the digit count, and other program control information.

The ringing register is used as a storage medium by the ringing and answer detection program. It is held for the period from the completion of dialing through the establishment of the talking connection. The path memory annex of the ringing register consists of seven words and contains the path memory necessary for the connections from the originating line to an audible tone trunk, from the terminating line to the ringing trunk, and the reserved path from the originating line to the terminating line. The data area contains class information of the terminating line, a condensed version of the originating line class, and program control information.

At the completion of dialing, if the call is outgoing, the originating register is changed to an outpulsing register. The digit analysis program does this by changing the state identifier of the register. The program also seizes a block of temporary memory and links this to the newly designated outpulsing register. The address of this block of temporary memory is stored in the first word of the path memory annex of the outpulsing register. The network path memory of (1) the connected path from the connections from the originating line to the digit receiver, (2) the connected path from the transmitter to the outgoing trunk, and (3) the reserved path from the line to the outgoing trunk is stored in this five-word temporary memory block. The data area of the outpulsing register contains the originating class information, dialed directory number, a route index specifying the first-choice outgoing route, and program control data.

The disconnect register is seized upon recognition of a disconnect and

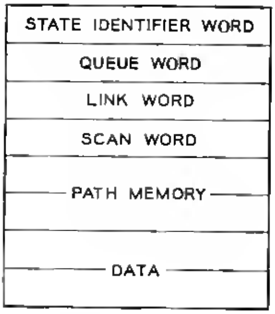

Fig. 14 — Typical call control register format.

is used by the disconnect program for timing and scanning. The path memory annex of the disconnect register consists of three words and contains the path information for a line-to-line, or line-to-trunk, connection. The data portion contains program control information.

The linking of call control registers is a one-way circular link. That is, if call control registers A, B, and C are associated with a call at a particular time, then register A contains register B's address in its link word; register B contains C's address; and register C contains A's address. Should a call program controlling this call decide to release register B, then the linkage is updated such that register A contains register C's address and register C contains A's address. Fig. 14 shows a typical call control register layout.

4.5 *Service Routine Registers*

A wide variety of registers exist to store data for use by service routine programs. The call charge register, peripheral order buffer, and coin control register are examples of service routine registers. The size and layout of these registers vary markedly.

The call charge record register has a layout identical to that of a call control register. The path memory annex of the call charge register is three words in length. The linking between a call charge register and a call control register is implemented in the same manner as the linking between call control registers.

The coin control register and peripheral order buffer contain primarily call control data and do not have the standard call control register layout, nor are they linked to a call control register in the previously described manner. They are used exclusively by the associated service routine program.

4.6 *Network Memory*

A portion of call store is reserved for the purpose of recording the busy-idle condition of the network links and junctors. This memory block is commonly referred to as the network map and is used by the network program in establishing or reserving network connections. In addition to the network map, a word of call store memory is assigned for every junctor terminal appearance on a line link network and for every trunk terminal appearance on a trunk link network. There is a direct relationship between a terminal and the address of its assoeiated word. These words for junctor and trunk terminals are commonly referred to as path memory for lines and path memory for trunks, respectively.

The information in the path memory for trunks, together with the trunk network number, uniquely specifies a junctor's terminal and the network links used in the trunk link network. Translation and eonversion programs facilitate the derivation of the address associated with the junctor terminal in the line link network. The network numher of the line junctor terminal, together with the contents of the path memory for lines, uniquely specifies the line and the links used in the line link network.

When no call control register is associated with a line-to-trunk eonnection, the path memory for lines contains the line equipment number of the No. 1 ESS customer and some control information specifying originating or terminating line, speeial treatment, coin line, and flash permission. The path memory for trunks contains a junctor network numher and control information specifying originating or terminating terminal, and flash permission for the No. 1 ESS customer.

When no eall register is needed on a line-to-line eonnection, each line junctor terminal word contains a customer's line equipment identification and control information. Translation programs facilitate the derivation of the address of either junctor terminal, given the other end.

When a call control register is associated with a eonnection, the address of the register is placed in the word, which usually holds the path memory for trunks on a line-to-trunk eonnection. On a line-to-line connection, the address of the register is placed in the words which normally hold the path memory for lines. In both cases, the displaced path memory is stored in the call control register in the area called the path memory annex.

4.7 *Recent-Change Register*

Sinee the translation tables are stored in the program store, which is not changeable hy the program during normal operation, an area of

temporary memory is set aside to provide an alternate location for the day-to-day administration of line number changes, new connections, disconnected lines, routing changes, etc. When this recent-change area is filled, the data are transferred to the program store's twistor cards by replacing them with new cards written in the program store card writer, a part of the master control center.

The translation program searches the recent-change register for a requested translation before going to the program store's tables, because there is a possibility that a change might have been made on the data.

Fig. 15 shows the principal blocks of temporary memory used for call processing and the flow of information from one to another.

V. PROCESSING AN INTRAOFFICE CALL

5.1 *Detection of Origination*

Fig. 16 demonstrates the role played by the program, the memory, and the equipment involved when a request for service is initiated. The supervisory line scan program examines the line ferrod sensor condition, with its associated line supervisory memory, approximately ten times per second. Upon detecting a line ferrod sensor in a saturated state and its line supervisory memory in an idle state, the program recognizes an origination. The program enters the line equipment number (LEN) in the line service request hopper.

5.2 *Connection of Line to Digit Receiver*

The first action of the dialing connection program, as illustrated in Fig. 17, is to examine the line service request hopper for an entry. Upon detecting an entry, the dialing connection program seizes an originating register and stores the customer's line equipment number in it (from the line service request hopper). After storing the line equipment number, the dialing connection program transfers control to the translation program, giving it the calling customer's line equipment number. The translation program returns with the originating line class information, consisting of: (1) TOUCH-TONE or dial pulse receiver required; (2) class of line (manual, individual, party, coin); (3) type of service (flat rate, message rate). The dialing connection program stores the originating class information in the originating register, then seizes and initializes a peripheral order buffer (POB). The dialing connection program next transfers control to the network control program, giving it the customer's line equipment number, the originating register's address, and a code for the type of receiver.

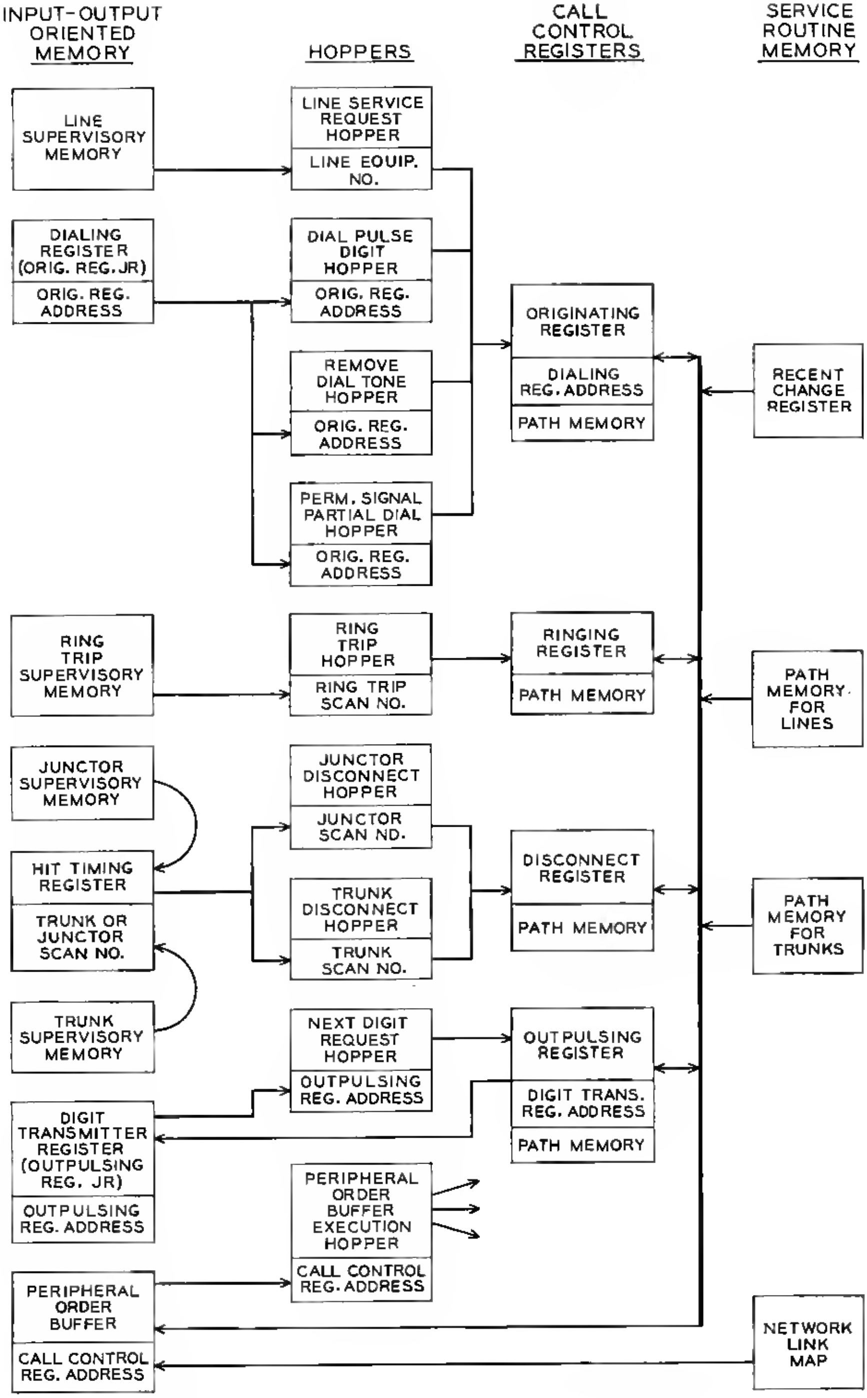

Fig. 15 — Temporary memory used for processing calls.

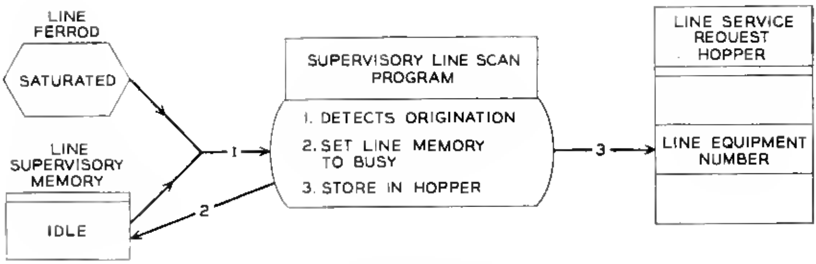

Fig. 16 — Detection of origination.

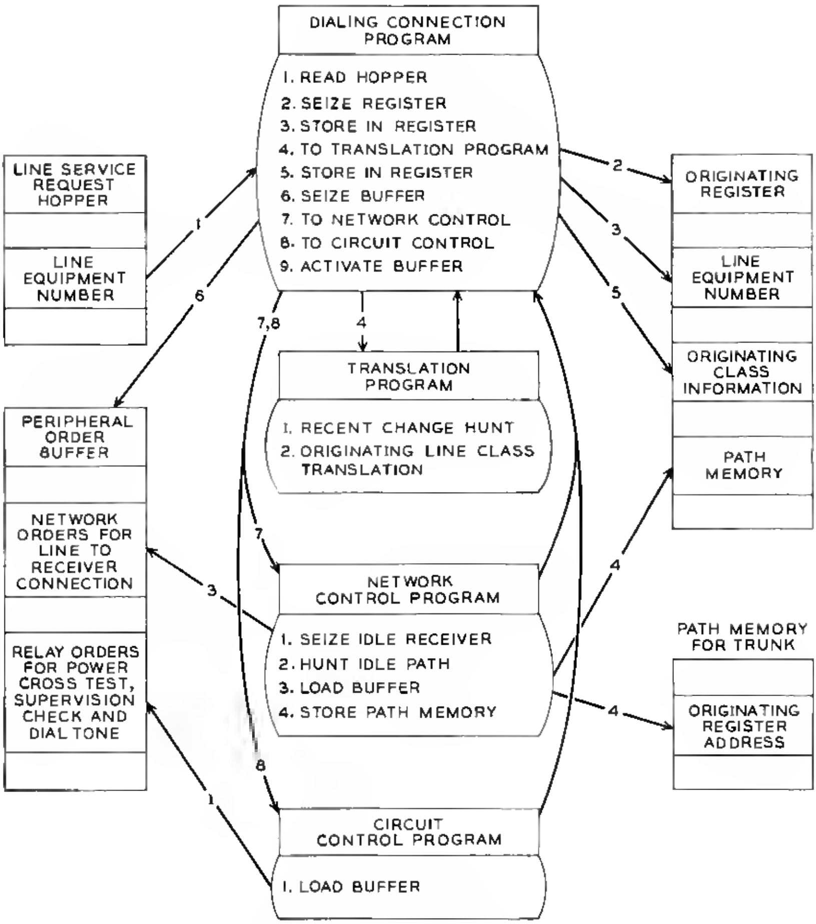

Fig. 17 — Initial actions for connection of line-to-digit receiver.

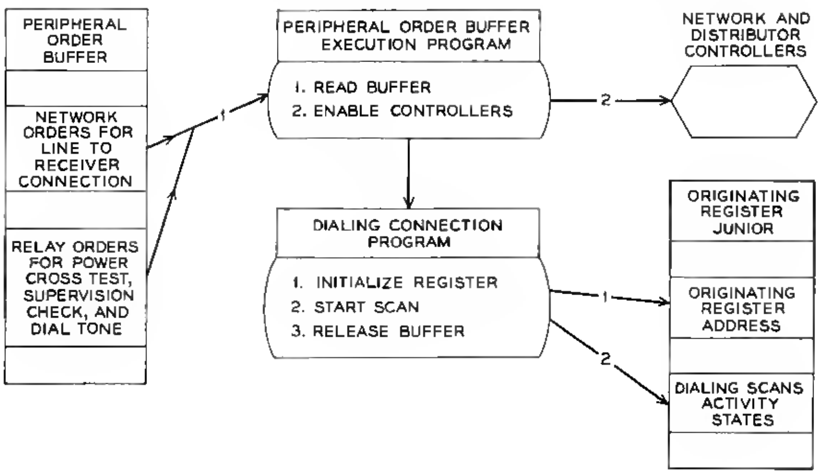

Fig. 18 — Final actions for connection of line-to-digit receiver.

The network control program loads the POB with instructions to establish the network connection between the customer's line and the receiver's trunk network number. The circuit control program loads the relay and scan operations required to perform the power cross test, transfer of supervision check, and application of dial tone. After completion of the loading, program control is returned to the dialing connection program which activates the POB.

As shown in Fig. 18, the POB execution program causes the instructions in the POB to be carried out. The successful execution of these instructions establishes a configuration as shown in Fig. 19; the originating line is connected to the digit receiver by a path through the line link and trunk link networks. Dial tone is applied to the originating

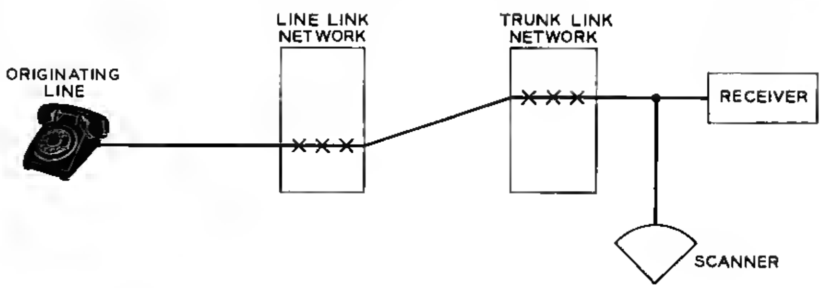

Fig. 19 — Receiver connection.

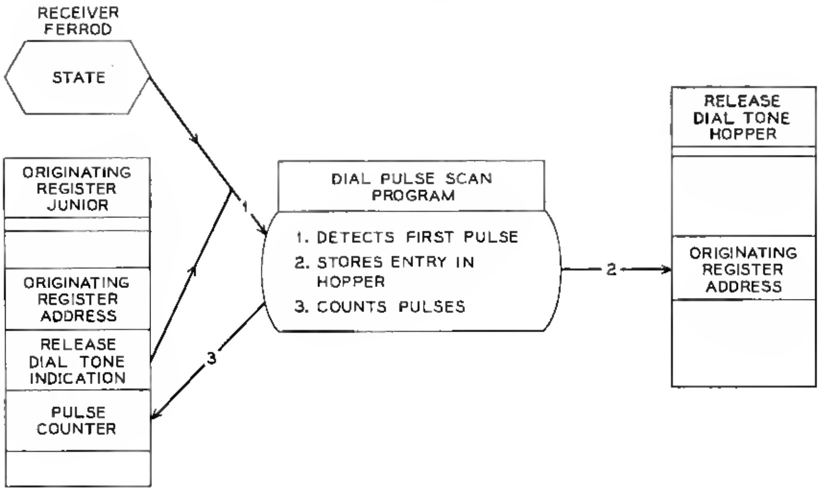

Fig. 20 — Detection of first pulse.

line, and supervision for abandonment is performed at the digit receiver. Upon successful execution of the instructions in the POB (as shown in Fig. 18), control returns to the dialing connection program. The dialing connection program releases the POB, stores the originating register address in the originating register junior, and sets indications in the originating register junior which initiate scanning for dial pulses, abandons, interdigital, permanent signal, and partial dial timing.

5.3 *Digit Analysis*

5.3.1 *Release of Dial Tone*

As shown in Fig. 20, the dial pulse detection program examines the ferrod associated with the pulsing relay of the receiver, and the originating register junior, to count dial pulses and to recognize the first pulse of the first digit. When the first pulse of the first digit is detected, the dial pulse scan program stores the originating address in the remove dial tone hopper and increments the pulse counter.

The digit analysis program (as shown in Fig. 21) regularly examines the remove dial tone hopper. On detecting an entry, the digit analysis program seizes and initializes a POB. The digit analysis program then transfers control to the circuit control program, giving it the receiver's trunk network number. The circuit control program loads the necessary

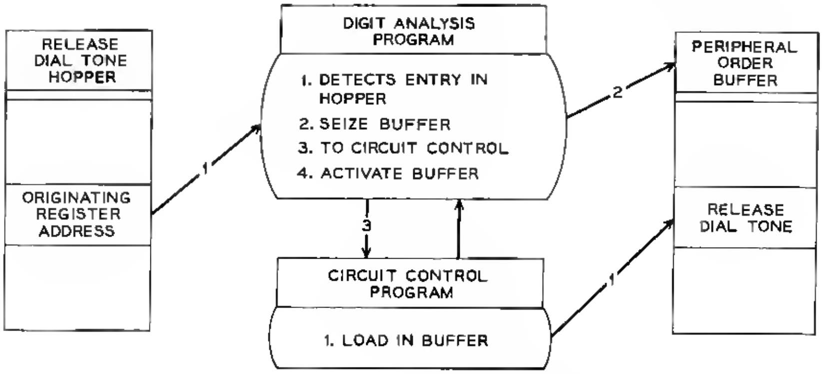

Fig. 21 — Initial actions for the release of dial tone.

instructions in the POB to release dial tone and then returns to the digit analysis program, which then activates the POB.

Upon successful execution of the POB (as shown in Fig. 22), control returns to the digit analysis program. This program marks a dial tone released indication in the originating register and releases the POB.

5.3.2 *Reception of Digits*

As shown in Fig. 23, if the receiver ferrod remains in a saturated state for a period of 120 to 240 milliseconds, the abandon-interdigital timing

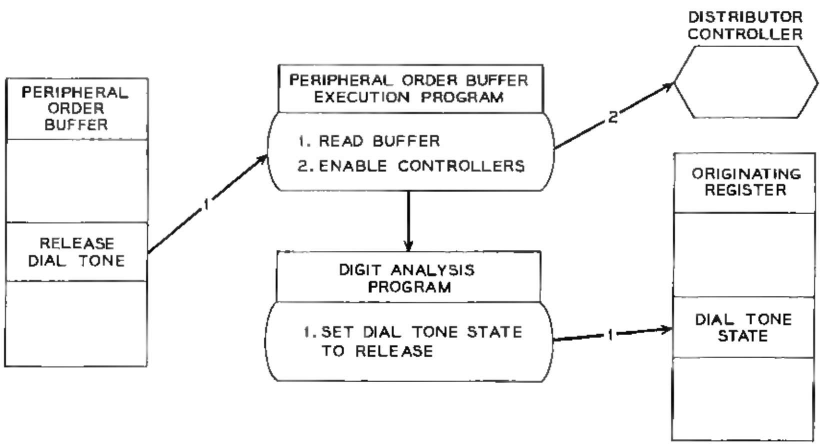

Fig. 22 — Final actions for the release of dial tone.

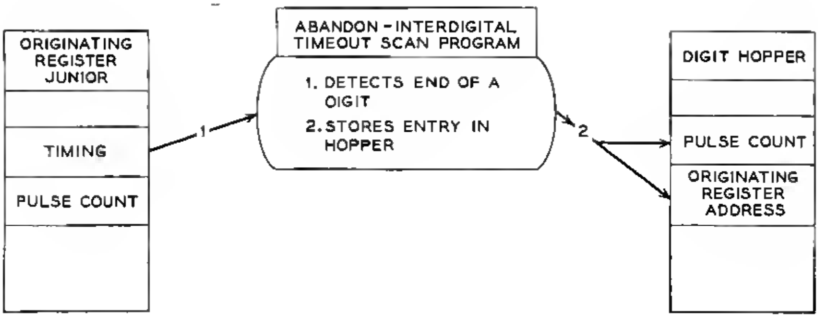

Fig. 23 — Reception of digits.

program determines that this is the end of a digit. The program interrogates the originating register junior for the pulse count and the originating register address and stores both items in the dial pulse digit hopper.

The digit analysis program (as shown in Fig. 24), scheduled by the executive control program, detects the entry in the dial pulse digit hopper, stores the pulse count in the originating register, and increments a digit counter. When the digit analysis program recognizes that the third digit has been received, it delivers the first three digits to the translation program. The translation program returns the following three-digit class information to the digit analysis program: (1) special service code dialed; (2) invalid code dialed; (3) interoffice code dialed,

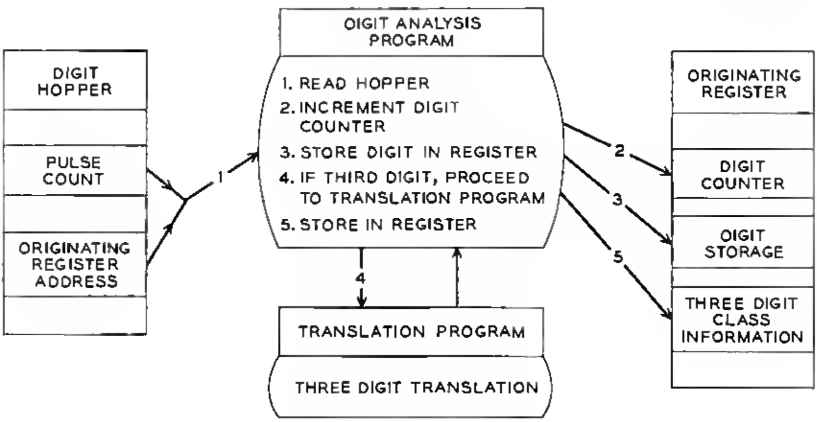

Fig. 24 — Analysis of third digit.

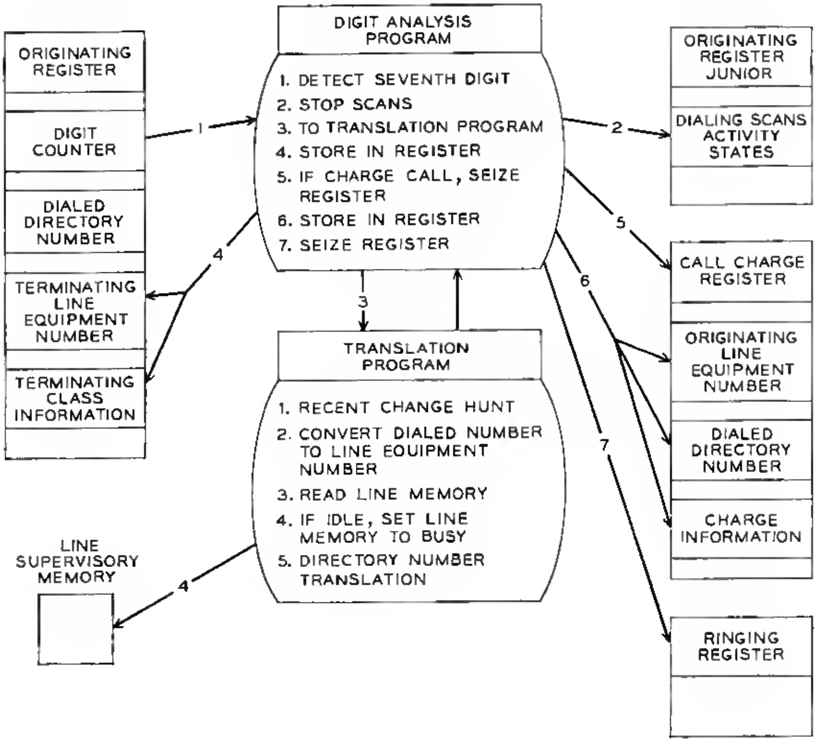

Fig. 25 — Analysis after end of dialing.

expect seven digits; (4) interoffice code dialed, expect ten digits; (5) intraoffice code dialed; and (6) charge call or free call.

5.3.3 *End of Dialing*

On the intraoffice call of this example, when the digit analysis program determines that the entry in the digit hopper is the seventh digit (as shown in Fig. 25), it shuts off the scan programs that detect abandon-interdigital time-outs, dial pulses, permanent signals, and partial dials by properly marking the originating register junior. The digit analysis program transfers to the translation program and requests a directory number translation. The translation program converts the directory number to a terminating line equipment number and terminating class. The translation program examines the terminating line's supervisory memory to see whether the line is busy. If idle, it marks the line super-

visory memory busy and then extracts the directory number translation. The directory number class information consists of: (1) busy line found, (2) invalid number, (3) idle line found, (4) busy but special treatment, (5) temporary transfer activated, and (6) trunk group found. The translation program places this information in its buffer memory so that it can be passed to the digit analysis program, which in turn stores this information in the originating register. The digit analysis program determines whether it is a chargeable call. If chargeable, a call charge register is seized, initialized, and linked to the originating register. The digit analysis program stores in the call charge register the originating line equipment number, charge information, and the dialed directory number. The digit analysis program then seizes and initializes a ringing register, links the ringing register with the originating register and call charge register, and then transfers control to the ringing and answer detection program.

5.4 *Ringing and Answer Detection*

5.4.1 *Establishing the Ringing Connection*

The ringing portion of the ringing end answer detection program (as shown in Fig. 26) seizes and initializes a POB and transfers to the network control program after giving it the originating register and ringing register addresses. The network control program idles the receiver, seizes idle ringing and audible ringing tone circuits, hunts an idle path from originating line to the audible tone circuit, hunts an idle path from the terminating line to the ringing circuit, reserves a talking path between the originating line and the terminating line, and loads the POB with instructions to establish two connections. The first connection is from the originating line to the audible ringing tone circuit. The second is from the terminating line to the ringing circuit. It also stores the path memory specifying the above network configuration in the ringing register path memory annex. The network control program returns control to the ringing program, which requests the circuit control program to load the POB with instructions to control relays and scan actions in the two circuits. On return, the ringing program releases the originating register and activates the POB.

As shown in Fig. 27, after the POB execution program successfully executes the instructions, control returns to the ringing program. The final actions in establishing a ringing connection are to set the audible tone circuit supervisory memory in a state such that the trunk super-

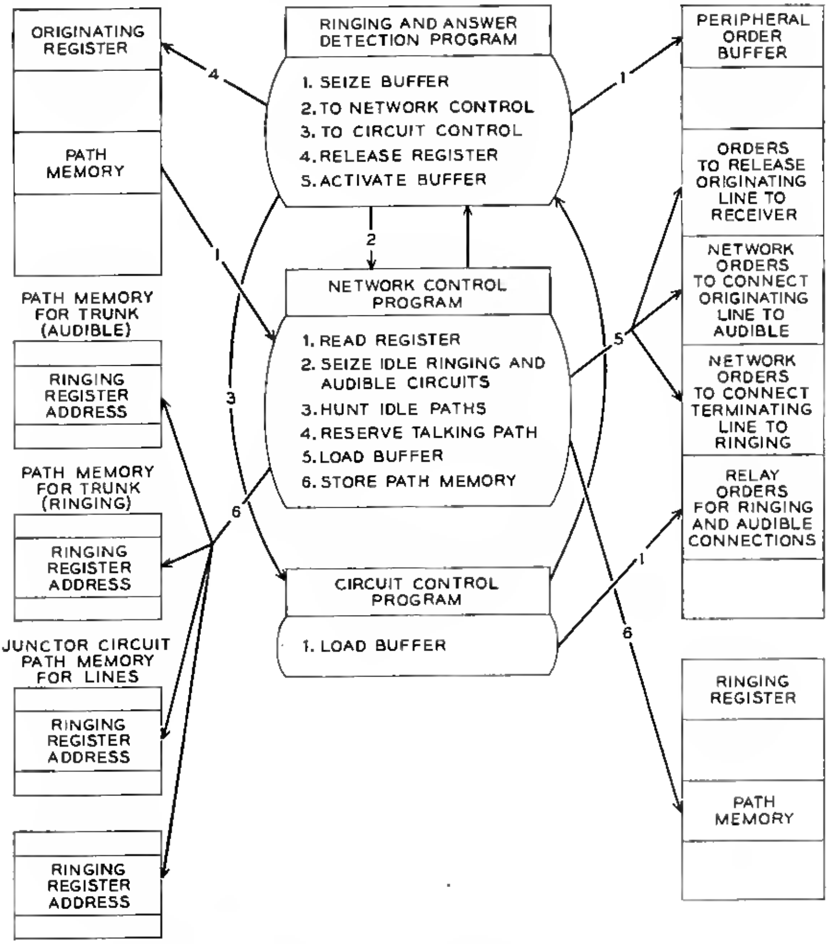

Fig. 26 — Initial actions for the ringing and audible connection.

visory scan program will detect a disconnect and the ringing circuit supervisory memory in a state such that the ringing trip scan will detect an answer by the called customer.

The successful execution of the POB actions in setting up ringing establishes the configuration shown in Fig. 28. The originating line is connected to an audible ringing tone circuit through the line link and trunk link networks; the terminating line is connected to the ringing circuit by a connection through the line link and trunk link networks; and a path through the line link network to a junctor circuit is reserved between the originating and terminating line. Supervision of the origi-

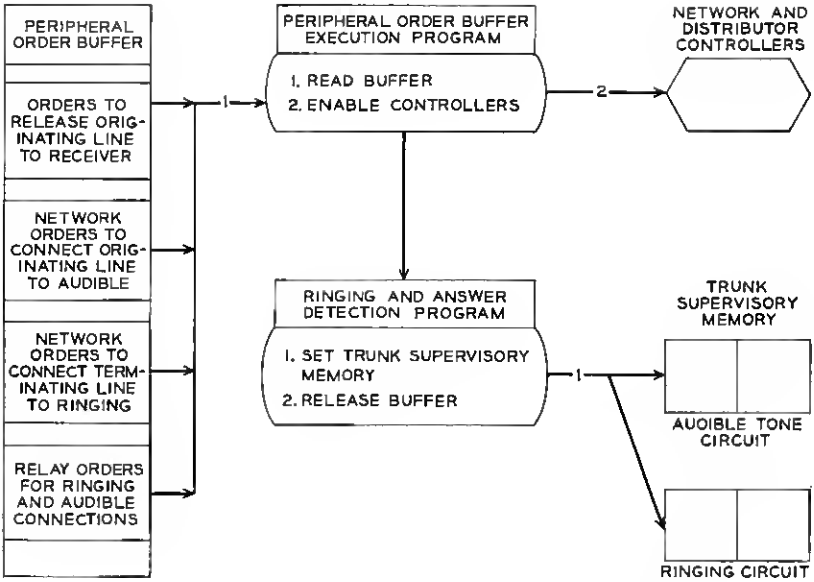

Fig. 27 — Final actions for the ringing and audible connection.

nating line is maintained at the audible ringing tone circuit, and the terminating line is supervised at the ringing circuit.

5.4.2 *Answer Detection*

The ring trip scan program (as shown in Fig. 29) examines the ring trip ferrod and the ringing circuit supervisory memory ten times per second. If the ring trip scan program detects the ring trip ferrod in an

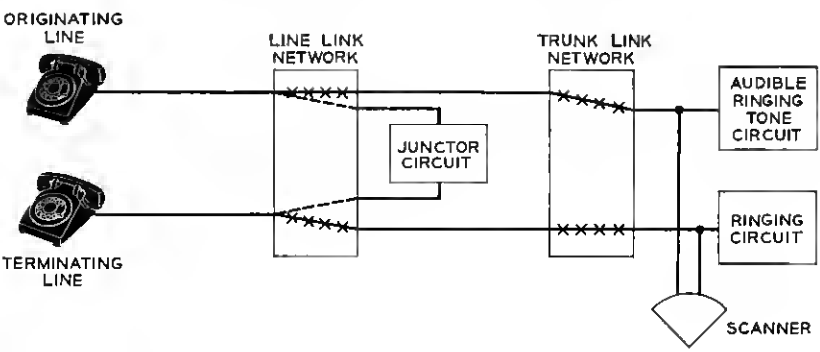

Fig. 28 — Ringing and audible connection.

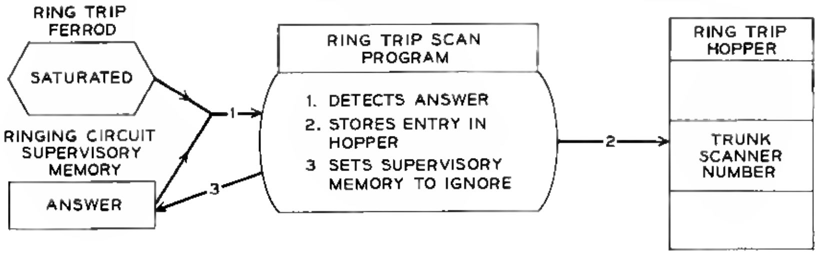

Fig. 29 — Detection of answer.

off-hook state and the ringing supervisory memory in an active state, it recognizes this condition as an answer. The ring trip scan program sets the ringing circuit supervisory memory to the ignore state and loads the trunk scanner number in the ring trip hopper. The answer detection part of the ringing and answer detection program (as shown in Fig. 30), when scheduled by the executive control program, examines the ring trip hopper. Upon detecting an entry, the answer detection program delivers the trunk scanner number to the translation program, which translates the trunk scanner number to its trunk network number and to the address of its associated path memory word. This information is then made available to the answer detection program. It seizes and initializes a POB and sets the audible trunk supervisory memory to the "ignore" state. It then transfers to the network control program, giving it the addresses of the ringing and call charge registers.

The network control program loads the POB with the instructions necessary to release the connection between the originating line and the audible ringing tone circuit, to release the connection between the terminating line and the ringing circuit, and to establish a talking path between the originating and terminating lines. The network control program also (1) idles the ringing and audible tone circuits (2), loads information associated with the talking path in the call charge register's path memory annex, and (3) places the address of this call charge register in the junctor's path memory words. The network control program then returns to the answer detection program, which requests the circuit control program to load the necessary relay and scan instructions to close the talking path. Then the answer detection program activates the POB.

As shown in Fig. 31, after the instructions stored in the POB are carried out, the answer detection program sets both sides of the junctor supervisory memory to busy, releases the POB, releases the ringing

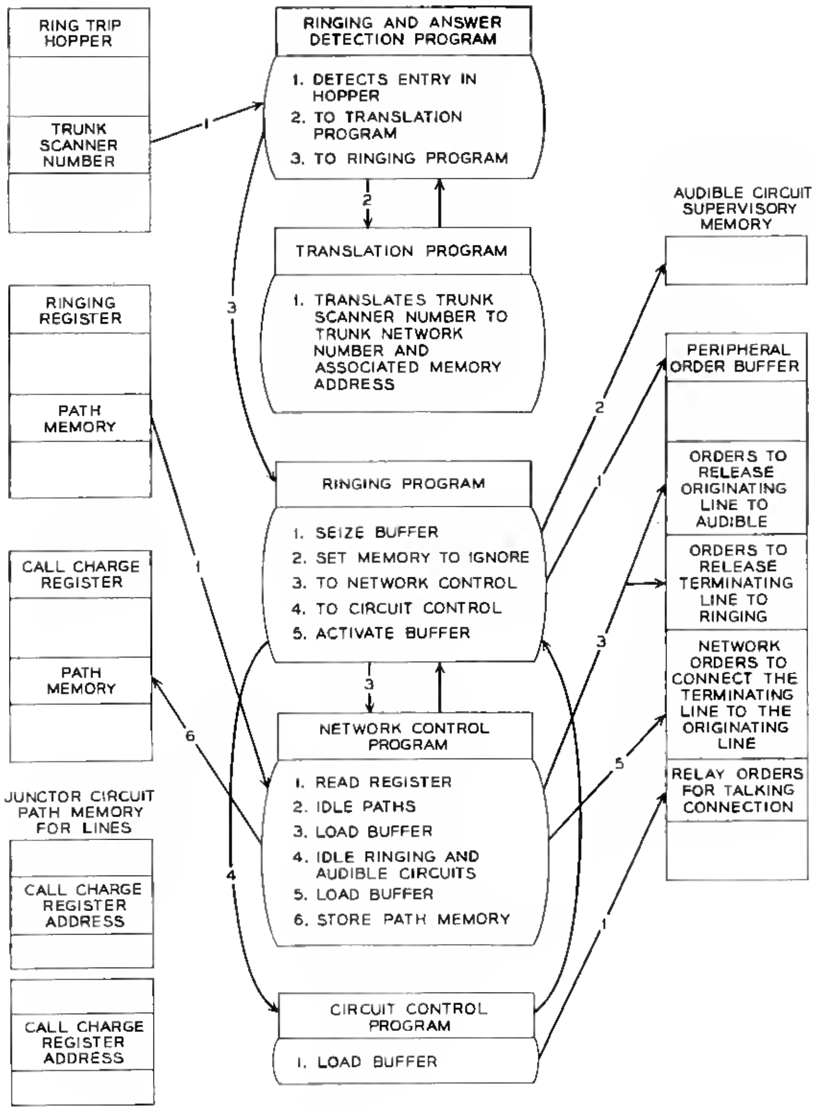

Fig. 30 — Initial actions for the talking connection.

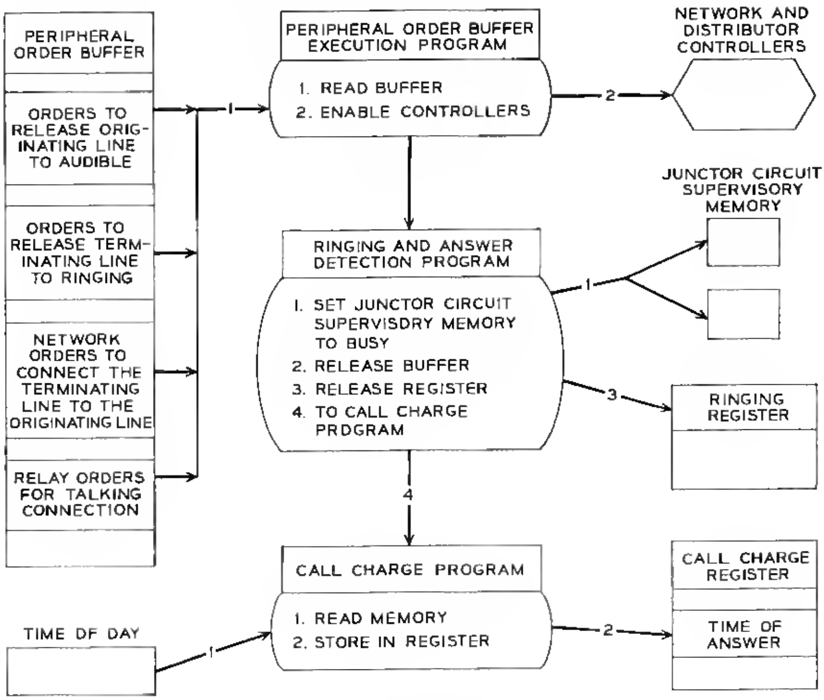

Fig. 31 — Final actions for the talking connection.

register, and transfers to the call charge program. The call charge program enters the time of answer (after reading the time of day) in the call charge register.

The talking connection between originating and terminating lines is established (as shown in Fig. 32) through the line link network. Super-

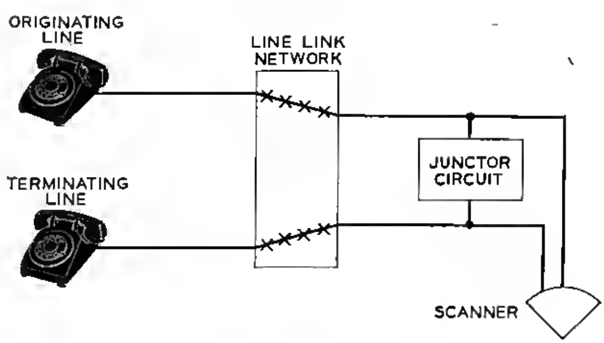

Fig. 32 — Talking connection.

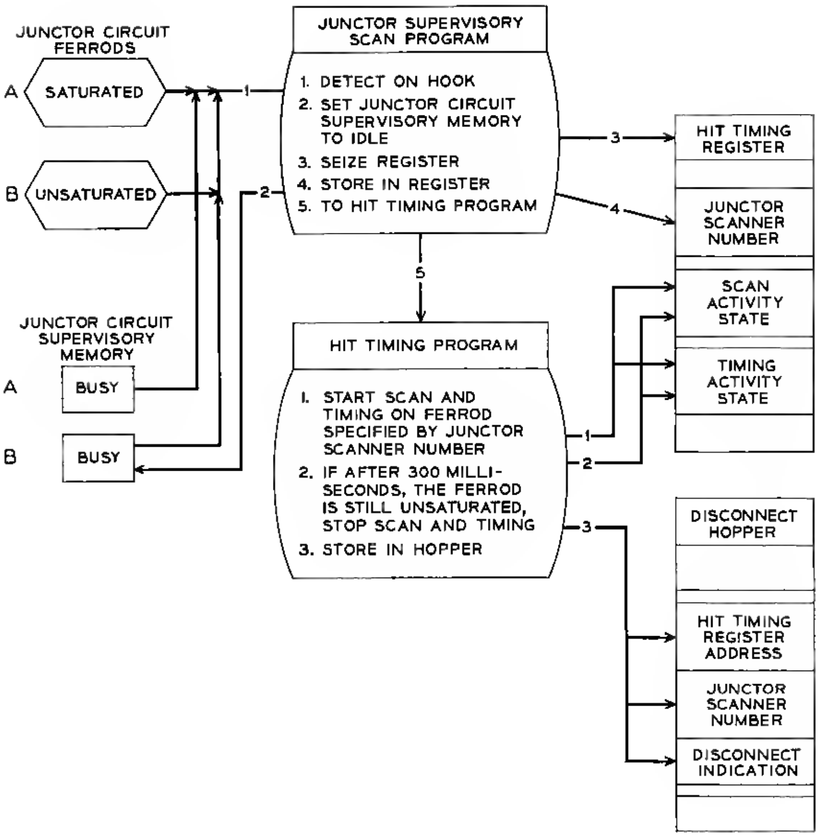

Fig. 33 — Detection of on-hook and hit timing.

vision of the originating and terminating lines takes place at the junctor circuit. The call charge register is in control of the call up to the time of disconnect.

5.5 *Disconnect*

Ten times per second the junctor supervisory scan program (as shown in Fig. 33) examines the state of the junctor ferrod and the junctor supervisory memory. If the junctor ferrod is unsaturated and the junctor supervisory memory (side B, Fig. 33) is in the busy state, the junctor supervisory scan program sets the junctor supervisory memory (side B) in the idle state. The junctor supervisory scan program then seizes and initializes a hit-timing register by placing the junctor scanner

number in the hit-timing register to start a directed scan of the junctor ferrod.

Three hundred milliseconds after the initial entry is stored in the hit-timing register, the hit-timing program reads the ferrod specified by the scanner number, and, if the ferrod still indicates on-hook, it recognizes a disconnect. The hit-timing program enters the junctor scanner number, the hit-timing register address, and a disconnect indication in the junctor disconnect hopper.

Later, the disconnect program (as shown in Fig. 34) removes the entry from the junctor disconnect hopper and transfers to the translation program after giving it the junctor scanner number. The transla-

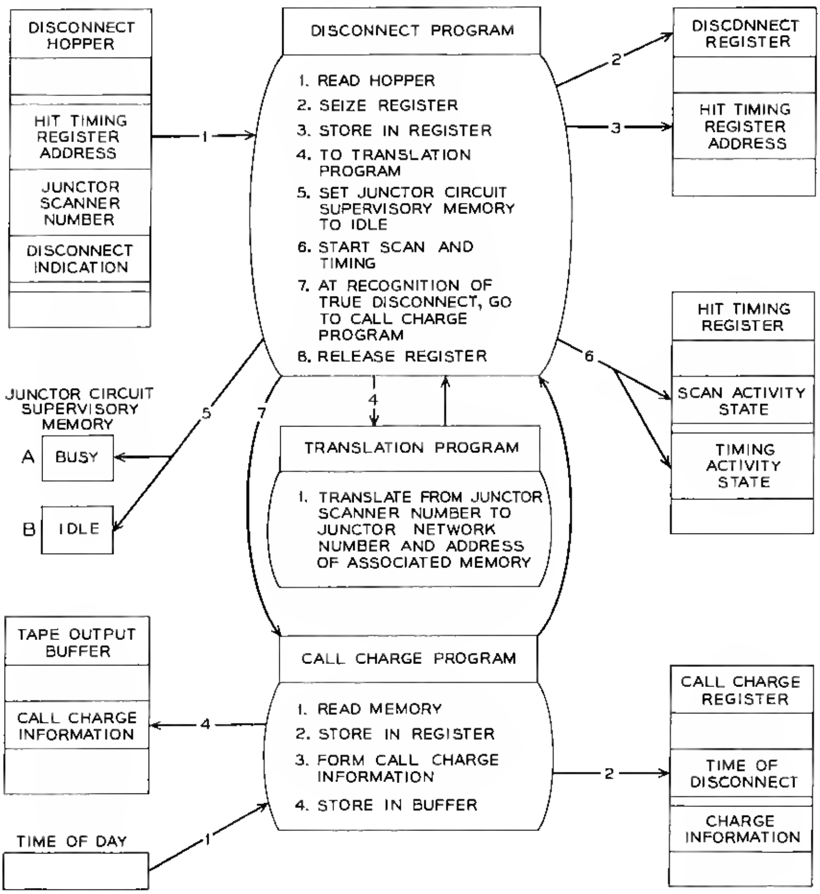

Fig. 34 — Detection of disconnect and charging actions.

tion program translates the junctor scanner number to the network numbers of the junctor terminals and obtains the addresses of the associated path memory. The translation program then returns tbese to the junctor disconnect program. The disconnect program seizes a disconnect register, stores in it the junctor network numbers and the hit-timing register address, sets the junctor supervisory memory (side A, Fig. 34) to the idle state, and links a disconnect register witb the call charge register. The call charge then records disconnect time in the call charge register. From the call charge register the disconnect program determines that the originating customer has disconnected. The disconnect program also initiates directed scans of the both junctor circuit ferrods. If the called customer disconnects or the calling customer reoriginates before 10 to 12 seconds have elapsed, the disconnect program stops the directed scans, releases the hit-timing register and transfers to the call charge program after giving it the call charge register address and a disconnect indication.

The call charge program loads the charge information into the tape output buffer. The call charge program returns control to the disconnect program. As shown in Fig. 35, the disconnect program seizes and initial-

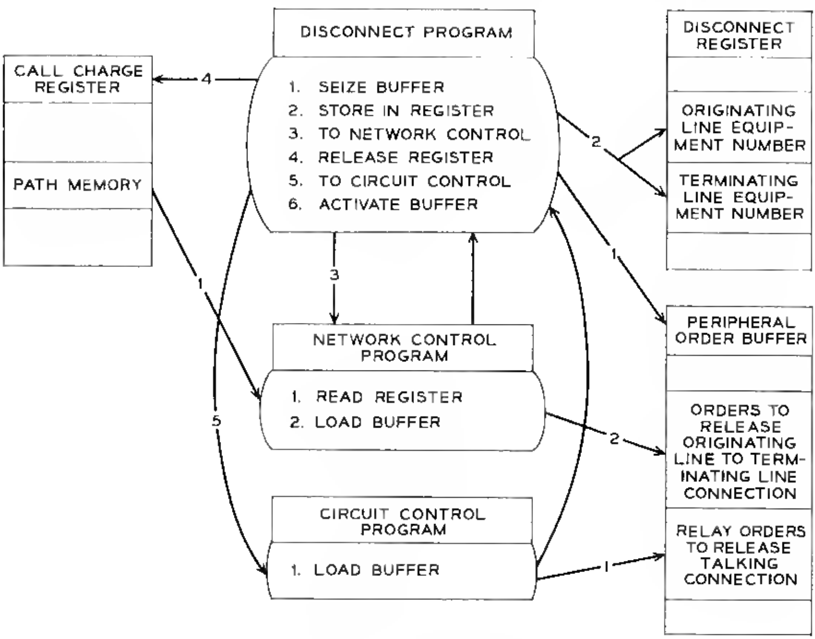

Fig. 35 — Initial disconnect actions.

izes a POB and transfers control to the network control program, giving it the call charge register address. The network control program loads the POB with the network actions necessary for restoration of the line ferrod. The network control program then returns to the disconnect program, which transfers to the circuit control program for the loading of the necessary relay actions. On return, the disconnect program releases the call charge register and activates the POB.

As shown in Fig. 36, after the relay orders stored in the POB are carried out, the disconnect program releases the POB and delivers to the translation program the originating and terminating line equipment numbers. The translation program converts the line equipment numbers to their line memory addresses and makes these available to the disconnect program. The junctor disconnect program sets the originating and terminating line supervisory memory to the idle state and releases the disconnect register.

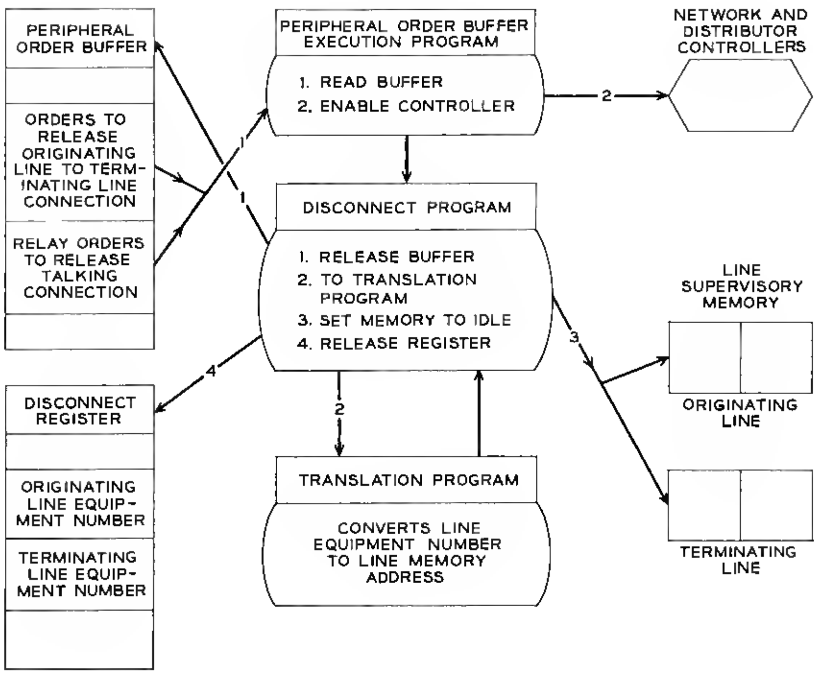

Fig. 36 — Final disconnect actions.

VI. CONCLUSION

The No. 1 ESS solves the problem of interconnecting telephone customers by centralizing the decision-making and the memory required to process telephone calls in an electronic data processor. As a result, trunk and service circuits have been greatly simplified.

The foregoing pages have described the manner in which the program, aided by circuits and by temporary memory, processes telephone calls. A simple intraoffice call has been used to illustrate the procedure followed in processing a particular type of call. However, the No. 1 ESS must offer many other services; hence programs must be provided to process other types of calls. The basic framework described here is supplemented in order to offer the full range of modern telephone services.

Although the variety of telephone services and equipment results in a large program to control the system, the use of a stored program offers an economical means to accomplish many present switching tasks and a flexible means for accomplishing the numerous future switching functions.

VII. ACKNOWLEDGMENT

Many of our colleagues have contributed to the planning necessary to implement call processing in the No. 1 ESS. Many of these contributions are discussed in greater detail in the other papers included in this issue of the Bell System Technical Journal. In addition, the authors acknowledge the work of numerous members of the systems engineering, program system design, and programming organizations concerned with the No. 1 ESS.

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